Effect of Instruction on Walking and Turning Performance in Individuals with Parkinson's Disease

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ABSTRACT

Parkinson’s disease (PD) is characterized by postural instability and gait impairment. Verbal instructions can reduce postural sway and improve gait performance in PD. For gait, this evidence is limited to unobstructed straight-path walking. As falls in PD often occur when turning, the purpose of this thesis was to determine if instructions can benefit turning performance in this population. Twelve individuals with PD performed two walking tasks (normal walking, walking with a 180 degree turn) under four instruction conditions (no instruction, take big steps, make larger trunk movements, focus on end and/or turn point). Task duration and trunk yaw and roll sway were calculated. In general, the results demonstrated that the instruction to take big steps improved performance for both tasks compared to providing no instruction or externally based instruction. These results suggest that instructions related to step amplitude may facilitate walking and turning performance in PD.

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CHAPTER ONE: Review of Literature

1.1 Parkinson's Disease

1.1.1 Introduction

Parkinson's disease (PD), first described by James Parkinson in 1817, is a neurodegenerative disorder that alters dopamine levels within the brain (Parkinson, 1817). Symptoms are typically encountered only when there has been an approximate 80% reduction in nigrostriatal dopaminergic neuron production (Fahn, 2003). As the disease progresses, further loss of dopamine concentrations within the putamen occur resulting in further motor symptom complications (e.g., slowness of movement). This debilitating disease has been reported to affect 1 to 1.5 million people in the United States (Hou & Lai, 2008) and approximately 100,000 people in Canada (*Parkinson's disease: Social and economic impact*., 2003). In addition, direct costs related to PD (e.g., physician and hospital care, drugs, research) have been reported to be upwards of 87 million dollars per year in Canada (*Parkinson's disease: Social and economic impact*, 2003). Parkinsonism can be classified into three major categories; primary Parkinsonism, secondary Parkinsonism, and parkinsonism-plus syndromes (Fahn, 2003). Primary Parkinsonism is sometimes referred to as idiopathic Parkinsonism implying that the etiology is of an unknown cause (Fahn, 2003). The majority of the research has been conducted on individuals with idiopathic PD and this type of Parkinsonism is the primary focus for this thesis.

1.1.2 Motor Symptoms

There are four principal motor symptoms typically observed in individuals with PD. These symptoms are resting tremor, bradykinesia, rigidity, and postural instability

(Weintraub, Comella, & Horn, 2008). Symptoms usually appear asymmetrically initially affecting only one side of the body (Weintraub, et al., 2008). However, symptoms begin to spread to the other side of the body with the progression of the disease (Pallone, 2007).

Resting tremor is observed in 70-90% of individuals with PD (Fahn, 2003; Pallone, 2007). It is usually the first motor symptom that is observed and is acknowledged as the most obvious diagnosable sign of PD with its classical presentation of a "pill-rolling" trembling or shaking of the thumb and/or wrist that occurs at a frequency of 3-6 Hz (Fahn, 2003; Frank, Parl, & Rossiter, 2006). This symptom can be intermittent or constant, appear in some or all of the individual's extremities, and worsen in stressful or exciting situations (Pallone, 2007).

Bradykinesia affects approximately 80-90% of individuals with PD and refers to a general slowness of movement (Weintraub, et al., 2008). In addition to a reduction in the speed of movement, the magnitude of movement can be reduced as well. In general, bradykinesia can be defined as a difficulty in maintaining voluntary movement whereas akinesia, a sub-category of bradykinesia, is referred to as the lack of and/or difficulty in initiating voluntary movement. Bradykinesia can occur in the hands (i.e., reduced magnitude of writing), the arms and legs (i.e., reduced magnitude of arm swing and stride length when walking), and the face (i.e., reduced magnitude of facial expressions; Fahn, 2003). Since this symptom causes "global slowness", individuals with PD may be required to plan accordingly when performing activities of daily living (ADLs) as excessive fatigue may become an issue (Pallone, 2007).

Rigidity, or stiffness in the joints of the body, is another common symptom observed in individuals with PD. The amount of stiffness around the joint's range of motion (ROM) can fluctuate (i.e., “cog-wheel” rigidity) or be continuous in nature (i.e., “lead-pipe” rigidity; Frank, et al., 2006; Pallone, 2007). Rigidity is best detected in the distal parts of the limbs, specifically the wrist joint (Weintraub, et al., 2008). Stiffness within the extremities and trunk may contribute to the impaired ability to turn observed in individuals with PD (Crenna, et al., 2007; Frank, et al., 2006; Van der Burg, van Wegen, Rietberg, Kwakkel, & van Dieen, 2006).

Postural instability and alterations in gait may be considered the most disabling motor symptom for individuals with PD. Specifically, postural instability in PD can be attributed to reductions in amplitude and development of anticipatory postural adjustments (Burleigh-Jacob, Horak, Nutt, & Obeso, 1997; Horak, & Frank, 1993), complications in the ability to adjust the level of response to external perturbations (Bloem, Beckley, Remler, Roos, & van Dijk, 1995; Burleigh-Jacobs, et al., 1997; Horak, et al., 1993), and increased trunk and ankle stiffness when recovering balance (Carpenter, Allum, Honegger, Adkin, & Bloem, 2004). Postural instability has also been suggested to be influenced by both flexed and/or stooped posture and “freezing of gait” (Gray & Hildebrand, 2000). Individuals with PD have been noted to commonly take smaller and faster steps (i.e., festination), while freezing episodes typically occur during gait initiation, cessation, turning, and walking through narrow passages (Trail, Protas, & Lai, 2008). Interestingly, these symptoms usually become more noticeable as the disease progresses (Weintraub, et al., 2008). It is important to note that these changes in postural control and gait may be associated with an increased fall risk (Ashburn, Stack, Pickering, & Ward, 2001). As improvements in postural control have been known to respond poorly to dopamine replacement therapy (Bloem, et al., 1996; Weintraub, et al., 2008), novel non-pharmacological interventions need to be explored to address postural control and gait problems in individuals with PD.

1.1.3 Falls in Parkinson's Disease

Falls have been reported to incur both direct and indirect costs of approximately 20 billion dollars per year in North America (Weintraub, et al., 2008). When looking at the prevalence of falls in PD, it has been reported that individuals with PD have a 9-fold increased risk of sustaining recurrent falls compared to healthy age-matched controls, with a reported 50% falling at least once per year (Bloem, Grimbergen, Cramer, Willemsen, & Zwinderman, 2001). Other researchers have described recurrent falling as a common consequence of PD (Bloem, Hausdorf, Visser, & Giladi, 2004; Grimbergen, Munneke, & Bloem, 2004; Schrag, Jahanshashi, & Quinn, 2000). This increased falls incidence has resulted in individuals with PD having an elevated risk for being administered to hospitals (Temlett & Thompson, 2006) and/or nursing homes (Hely, et al., 1999) as a result of complications associated with falls. Falls have also been linked to disease severity (Ashburn, et al., 2001). Frequent freezing episodes during gait initiation and termination, and turning have also been linked to an elevated risk of falling in PD (Hou & Lai, 2008). Bloem and colleagues (2001) further report that most falls for PD patients occur while turning (24%), standing up (15%), and bending forward (16%). Importantly, all of these tasks require some form of trunk involvement. This may suggest that axial rigidity is a main concern when addressing falls prevention, especially during ADLs requiring turning.

PD is characterized by postural instability, gait impairment, and falls which can result in a loss of independence and have a detrimental influence on quality of life

(Bloem, van Vugt, & Beckley, 2001; Bloem, et al., 2001, Adkin, Bloem, & Allum, 2005). This instability or increased risk of falls may result from bradykinesia, rigidity, stooped posture, and/or shuffling gait. It appears that traditional antiparkinson medications have a negligible effect on postural instability and some researchers have reported that many falls occur during the self-reported optimal on medication state in PD (Bloem, et al., 2001). Thus, it is important to explore alternate therapeutic strategies for minimizing postural instability and improving gait in PD.

1.2 Verbal Instructions

1.2.1 Attention Focus

One method that has been proposed to improve postural instability in healthy young adults and more recently in individuals with balance and gait problems (i.e., stroke and PD) is the use of attention focus strategies. Attention focus strategies have been described as instructing the participant to focus on certain sources, without actually looking at the source (Wulf, Landers, Lewthwaite, & Toller, 2009). Therefore, attention focus strategies consist of directing attention to certain areas, theoretically still leaving one's visual system available to pick-up on any appropriate stimuli within the environment required for movement.

There are two broad types of attention focus instructions. The instructions may direct the individual's attention to an internal source (i.e., internal attention focus) or an external source (i.e., external attention focus). External attention focus instructions direct attention to the individual's *effects* of his or her movements on the environment while internal attention focus instructions direct attention to the individual's movements or movement patterns (i.e., head, trunk, legs, muscles, joint angles, etc; Wulf & Prinz, 2001). The content of attention focus instructions and the effects of these instructions on motor performance and learning have been extensively evaluated (Bell & Hardy, 2009; Canning, 2005; Castaneda & Gray, 2007; Ehrlenspiel, Lieske, & Rubner, 2004; Landers, Wulf, Wallmann, & Guadagnoli, 2005; McNevin & Wulf, 2002; McNevin, Shea, & Wulf, 2003; Perkins-Ceccato, Passmore, & Lee, 2003; Weiss, Reber, & Owen, 2008; Wulf, Mercer, McNevin, & Guadagnoli, 2004; Wulf, Weigelt, Poulter, & McNevin, Experiment 1 & 2, 2003; Wulf, Shea, & Park, 2001; Wulf & Su, Experiment 1 & 2, 2007; Wulf, Landers, Lewthwaite, & Töllner, 2009). Taken together, this research suggests that an external attention focus provides performance improvements and learning benefits beyond that of an internal attention focus or no specific attention focus instructions.

1.2.2 Constrained Action Hypothesis

The superior performance/learning benefit of an external attention focus has been explained by the constrained action hypothesis. This hypothesis states that in order for the 'natural' motor control processes associated with a movement to occur, conscious control (i.e., internal focus) to the mechanics of the movement should be avoided in order to reduce the neurological degrees of freedom associated with the movement (Wulf, et al., 2001; Wulf & Prinz, 2001). When performing and/or learning movements, one should incorporate an external focus of attention as this enables the motor control processes to organize in a more 'natural' manner, thus resulting in the production of an unconstrained and/or more automatic movement. The common coding hypothesis can be used to explain the constrained action hypothesis. This theory states that actions become more effective if they are planned in terms of their intended outcome, rather than their specific movement patterns (Prinz, 1997). Prinz (1997) further emphasizes that the only way to successfully complete a perceived action is through the ‘commensurate coding of the action’, which can only occur while attaining a ‘distant level of representation’ (i.e., further away from the body). It is only at this distant level of representation that the planning of an action occurs in a shared format with perception (Prinz, 1997). This ability to share the concurrent planning and outcome of an action appears to be best conducted while incorporating some form of external focus of attention as this type of attention focus provides a more ‘distant level of representation’. Therefore, it is only at this distant level of representation that the planning and perception of the action correctly occurs and this will theoretically enable a ‘natural’ unconstrained performance of the given task.

1.2.3 Factors that Influence the Effects of Attention Focus on Movement

Research has evaluated the effects of the performer’s skill level on the performance improvements associated with the different attention focus instructions. The general conclusion has been that improvements associated with attention focus depend on the individual’s skill level. For instance, highly skilled individuals have been found to improve performance when using an external focus of attention whereas other studies suggest that an internal focus of attention benefits lower skilled individuals (Castaneda & Gray, 2007; Perkins-Ceccato, et al., 2003; Wulf & Su, Experiment 1 & 2, 2007). It appears that an external focus of attention promotes the use of higher brain centers resulting in a more automatic performance of the task. However, it also appears that for lower skilled individuals, directing attention towards skill execution may result in additional performance benefits as the individual has yet to learn the required skills associated with the movement (Castaneda & Gray, 2007; Perkins-Ceccato, et al., 2003). In other words, the low skilled athlete is not ready to complete the skill automatically as movements such as a golf swing and baseball swing (i.e., sports that cited research used) require intricate coordination and force generation. This may also extend to individuals with PD as movements that were once automatic (i.e., standing, walking, and turning) may now be less automatic and require instructions to focus on certain areas of the body (i.e., feet, trunk) in order to improve performance. Furthermore, these instructions may be more or less effective depending on disease severity. That is, certain verbal instructions may be beneficial early on in the disease where the automaticity of movement may not be as affected while other instructional sets may provide additional benefits as the disease progresses due to a loss of automaticity of movement.

Studies have also investigated whether the individual has a preference for attention focus instruction (i.e., natural tendency to direct attention to an internal or external source). Wulf, Shea, & Park (Experiment 1, 2001) showed that there were individual preferences regarding attention focus. First, individuals preferred an initial internal attention focus preference when performing a stationary stabilometer balance task. However after sufficient practice, learners chose to move to an external focus of attention or the attention focus that promotes the best performance (Wulf, Shea, & Park, Experiment 1 & 2, 2001). Research has also evaluated the effects of forcing an individual to switch from a preferred to non-preferred focus of attention (i.e., forced-switch; Weiss, 2011; Weiss, et al., 2008). This forced-switch situation applied to coaches teaching players the way in which they believed to be correct, when in fact the player has his/her own perceived attention focus preference for learning. These studies have collectively found that there is no definitive disadvantage for using an internal focus of attention unless the individual had an external attention focus preference and was forced to use an internal attention focus (Ehrlenspiel, et al., 2004; Weiss, Reber, & Owen, Experiment 1 & 2, 2008). Thus, the efficacy of attention focus instruction may depend on individual attention focus preference especially in individuals with balance and gait problems.

Research has also been conducted examining the distance of the external attention focus from the body. External focus of attention instruction can be more proximal (i.e., directing attention to a source closer to the body), or more distal (i.e., directing attention to a source further away from the body). The added distance between the body and the external source has the potential to reduce the amount of interference between attention focus sources and promote the automaticity of the task. Studies that have investigated this effect have collectively concluded that a more distal external focus of attention results in superior performance compared to an internal focus of attention (Bell & Hardy, 2009; McNevin, et al., 2003). More specifically, while completing a static balance task with instructions to keep the platform in a horizontal position while focusing on either markers placed at the midline (i.e., far-inside) or the edges (i.e., far-outside) of the platform, reductions in postural sway and larger frequency/lower amplitude postural adjustments were reported during the retention phase when comparing the far-external to both the near-external and internal attention focus instruction conditions (McNevin, et al., 2003). The authors concluded that the use of an external attention focus instruction located in close proximity to the body (i.e., near), or the body itself (i.e., internal) appear to be synonymous and equally “constrain the regulatory processes involved in the control of balance” (McNevin, et al., 2003). McNevin and colleagues (2003) demonstrated that the notion of a distal external attention focus being better does not depend on location, as long as the instruction is distal in nature (i.e., both far-inside & far-outside produced similar results). Bell & Hardy (2009) examined attention focus distance during a more dynamic anxiety-provoking golf-chip shot task. Once again, regardless of the condition (i.e., no-anxiety or anxiety), a distal external focus of attention produced the greatest accuracy scores. It appears that the distal focus of attention enables higher brain centers to more self-naturally organize, resulting in the task being performed automatically, and ultimately performance benefits.

1.2.4 Attention Focus in Parkinson Disease

Attention focus instructions may be a viable means of counteracting postural instability typically seen in individuals with PD. Despite this potential benefit, few studies have been conducted that examine attention focus and its effects on postural instability in PD.

Landers, Wulf, Wallmann, & Guadagnoli (2005) first evaluated the effects of attention focus on standing postural control in PD. Individuals with PD, on medication, completed a condensed Sensory Organization Test which included the following three balance tasks (i.e., standing with eyes open with fixed support surface and visual surround; standing with eyes closed with fixed support surface and visual surround; standing with eyes open with sway-referenced support surface and fixed visual surround). Participants stood on rectangular pieces of contact paper (i.e., one positioned under each foot) that were placed on a force platform. An equilibrium score was used as a measure of balance and was expressed in a percentage format (i.e., 0% reflected large sway whereas 100% reflected little or no sway). Participants were first tested in a baseline condition (i.e., no attention focus instruction). This condition was followed by counterbalanced internal attention focus (i.e., concentrate on your feet) and external attention focus instruction (i.e., concentrate on the rectangles below your feet) conditions. For all conditions, participants were instructed to “look straight ahead”.

Results of the study showed that individuals with PD swayed more as task difficulty increased. For the easiest task (i.e., eyes open), individuals with PD swayed more when provided with internal attention focus instructions. This suggests that incorporating an internal attention focus can compromise relatively simple, presumably automatic, tasks. When examining fallers and non-fallers within this sample, fallers showed less sway on the most challenging task when provided with external attention focus instructions compared to internal attention focus instructions or no instructions at all. Thus, although no external attention focus benefit was found for the combined faller and non-faller groups, fallers did reveal the common external benefit previously described in other studies but only for the most challenging task (Wulf, et al., 2003). The authors concluded that the reason for only the most difficult task eliciting an external attention focus benefit was because individuals with PD tend to be more cautious during ADLs (i.e., directing attention to their movements, or internally; Landers, et al., 2005; Masters, Pall, MacMahan, & Eves, 2007). An external attention focus may counteract this behaviour and promote the utilization of more automatic control processes. The authors concluded that an external focus of attention improves postural instability in individuals with PD during more demanding tasks (Landers, et al., 2005).

Next, Wulf and colleagues (2009) set out to replicate the previous advantages found using an external attention focus in PD. However, this time the task was to use a uniformly more challenging static balance task. This challenging task was chosen as previous findings in PD (Landers, et al., 2005) showed that a certain degree of task difficulty is required in order to observe the benefits of an external attention focus (Wulf, Töllner, & Shea, 2007). The testing, conducted at the participant's home, had individuals stand and balance on top of a rubber disk that was placed on a portable force platform. All participants were instructed to "look straight ahead" while balancing on the disk. Additionally, participants were instructed to "stand still" (i.e., control), "focus on minimizing movements of your feet" (i.e., internal), and to "focus on minimizing movements of the disk" (i.e., external; Wulf, et al., 2009). Most participants were unable to remain standing for the duration of the trial therefore the longest segment of standing in each trial was used for analysis (i.e., average was 11.9 seconds).

Once again, the results indicated that postural sway was significantly reduced when participants adopted an external focus of attention (Wulf, et al., 2009). This finding was in comparison to both the internal focus of attention group and the control group. These results confirmed previous findings in PD stating that an external attention focus is optimal for balance performance (Landers, et al., 2005). Furthermore, since the internal attention focus and control groups were not significantly different from each other, the authors concluded that individuals with PD appear to choose a less optimal focus for remaining stable. The authors concluded that the previous notion of an external attention focus resulting in improved performance extends to individuals with PD during balance tasks.

Canning (2005) evaluated attention focus instructions for a more dynamic walking task in individuals with PD. The task consisted of being videotaped while walking 10 meters at a comfortable pace. This was performed under two baseline and two attention focus conditions. The baseline conditions consisted of walking with hands free and no instructions (i.e., single/none), and walking while carrying a tray containing four empty glasses and no instructions (i.e., dual/none). The experimental conditions consisted of walking while carrying a tray with instructions to "attend to maintaining big steps while walking" (i.e., dual/walk), and walking while carrying the tray with instructions to "attend to balancing the tray and glasses" (i.e., dual/tray). Baseline conditions were always tested first, followed by the experimental conditions presented in a random order. Three trials of each condition were performed, with only the third trial of each condition used for analysis (Canning, 2005).

The results of the study showed that participants walked slower, with shorter strides, but similar cadence when carrying the tray compared to walking with hands free (i.e., performance decreased under a dual-walking task). The key finding of this study was the comparison of baseline conditions to experimental conditions. Canning (2005) found that a significant improvement in walking performance (i.e., faster walking, with longer strides, but similar cadence) occurred when PD participants were told to attend to 'maintaining big steps' compared to the baseline condition with no attention focus. That is, improved performance (i.e., faster walking) was as a result of taking longer strides while maintaining the same number of steps per minute (i.e., cadence). This improved dual-task performance was to a level 'comparable' with the initial, hands-free baseline condition. Furthermore, walking performance deteriorated (i.e., walked slower, with shorter strides, and a reduced cadence) when participants were told to focus on the tray itself compared to the baseline condition with no attention focus (i.e., dual/none). Canning (2005) showed that focusing on 'taking big steps' (i.e., internal attention focus) resulted in superior walking performance, which did not support previous reports of the benefits of utilizing an external attention focus. It was argued that this finding was ‘not surprising given the motor impairments typically described in PD (Canning, 2005). Specifically, decreased velocity and stride length is thought to be due to a decreased automaticity of walking and it was not unexpected that instructions promoting a more conscious control of walking would improve performance. This study raised the question, does directing a performers attention focus towards the movement effect always provide the best means of improvement for the task?

Wulf and colleagues (2009) rebutted Canning’s (2005) conclusion stating that her results must not be taken at face value. Wulf and colleagues (2009) described that the reason for this is because both the act of walking and carrying a tray can be executed with an external or internal focus of attention. Therefore, without any information pertaining to where Canning’s (2005) participants’ specific attention focus was, no viable conclusion can be made simply based on activity type (i.e., taking bigger steps is an internal attention focus). Interestingly, Wulf and colleagues research (Landers, et al., 2005; Wulf, et al., 2009) on PD is typically within static balance tasks whereas Canning’s (2005) research was during a more dynamic balance task. There is the possibility that task constraints may affect the most optimal type of attention focus, but this is yet to be determined. Furthermore, there is a growing body of literature looking at how simple verbal instructions benefit individuals with PD during dynamic tasks such as walking.

1.2.5 Effect of Instruction on Walking in Individuals with Parkinson Disease

Skilled verbal instructions provide a means for counteracting motor problems associated with PD. Instructional sets have long been used to facilitate performance on a myriad of tasks. More specifically, previous research on instructional sets has focused primarily on straight path walking. These studies have found that performance improvements occur as a result of instructing individuals with PD to perform an activity while focusing on certain aspects of the given task. For example, instructing participants to walk while focusing on “taking long steps” (Lehman,Toole, Lofald, & Hirsch, 2005; Werner & Gentile, 2003), “taking big steps” (Baker, Rochester, & Nieuwboer, 2007), “the foot contacting the floor with each step” (Shaw, Huffman, Frank, Jog, & Adkin, 2011), “walking with large steps” (Behrman, Teitelbaum, & Cauraugh, 1998), “long strides” (Morris, Iansek, Matyas, & Summers, 1996; Lehman, et al., 2005; Behrman, et al., 1998; Baker, et al., 2007), to “think big” (Farley & Koshland, 2005), and to take a mental picture of a healthy age-matched controls step length (Morris, et al., 1996) have all shown improvements in multiple balance and gait measures. These improvements have been shown in stride length (Baker, et al., 2007; Behrman, et al., 1998; Farley & Koshland, 2005; Lehman, et al., 2005; Morris, Iansek, & Kirkwood, 2009; Shaw, et al., 2011; Werner & Gentile, 2003), gait velocity (Baker, et al., 2007; Behrman, et al., 1998; Lehman, et al., 2005; Farley & Koshland, 2005; Morris, et al., 2009; Shaw, et al., 2011; Werner & Gentile, 2003), and double support duration (Shaw, et al., 2011) with cadence measures typically remaining similar in nature (Canning, 2005; Farley & Koshland, 2005; Morris, et al., 1996). Furthermore, these improvements have been shown to be effective in both the short (i.e., one week retention test; Werner & Gentile, 2003) and long-term (i.e., four week retention test; Lehman, et al., 2005).

The improvements associated with “movement strategy training” (i.e., skilled verbal instructions) has been described as effective as it enables people with PD to utilize their frontal cortex to move faster, easier, and safer using some form of cognitive control

(Morris, 2000). This may be due to the fact that focusing attention on the “critical aspect” of the required movement results in the use of frontal-lobe strategies, which may compensate for the defective BG, typically associated with PD (Morris, 2000).

Multiple training techniques have been used on individuals with PD to improve mobility. For example, the use of attention focus (Galletly & Brauer, 2005), mental-rehearsal (Morris, 2006), visualization (Galletly & Brauer, 2005), visual cues (Dibble, Nicholson, Shultz, & MacWilliams, 2004), and auditory cues (Nieuwboer, Kwakkel, Rochester, Jones, van Wegen, & Willems, 2005; Thaut, McIntosh, Rice, Miller, Rathbun, & Brault, 1996) have all been researched. Even though several avenues exist for training movement strategies in individuals with PD, it is still unknown which strategy is the most optimal. Furthermore, external cues require either a constant auditory, visual, and/or proprioceptive cue to enable performance improvements. The use of these external cues to aid performance may not always be feasible for complex activities of daily life.

Research has started to evaluate the best means for providing movement strategies. A recent study conducted by Baker, Rochester, and Nieuwboer (2007) set out to determine the efficacy of both rhythmic and attentional cue strategies on gait during single and dual tasks in PD. Participants were required to complete two trials with each cue type in a randomized order. The instructions were as follows: “As you walk try to step your feet in time to the beat” (i.e., rhythmic), “think about taking big steps” (i.e., attentional), and “take a big step in time to the beat” (i.e., combination). The cueing types were performed under two cueing conditions, a single (i.e., walk alone) and dual task (i.e., walking with tray with 2 cups of water) condition. The results of this study indicated that for walking speed, both single and dual tasks under attentional and combination cues had a similar significant increase (Baker, et al., 2007). Similar results were found for step amplitude, and step frequency. The authors concluded that individuals with PD could use attentional strategies to increase step amplitude during both single and dual tasks. Furthermore, an attentional strategy can be used to normalize walking speed to that of healthy age-matched controls. In addition, it appears that simply instructing PD patients on attentional strategies is more effective for ADLs than rhythmic cues and just as effective as the combined strategy utilized within this study (i.e., rhythmic & attentional) (Baker, et al., 2007). Therefore, this may provide proof for the added feasibility of attentional strategies (i.e., skilled verbal instructions) compared to traditional forms of movement strategy training used on PD patients (i.e., rhythmic cues).

Shaw, Huffman, Frank, Jog, and Adkin (2011) examined whether the benefit of instruction to straight path walking in PD was influenced by task constraints (i.e., speed of completion). This study consisted of walking a straight travel path in a no instruction condition and a skilled focused instruction condition. In the no instruction condition, participants were told to walk with no additional instructions provided. In the skilled instruction condition, participants were instructed to "focus on the foot contacting the floor with each step". In addition, both instruction conditions were completed at the participants 'preferred' and 'as fast as possible' pace. The results of this study reported differing effects of instruction depending on the task constraint (i.e., walking pace). When PD participants walked at a preferred pace while incorporating a skilled focused instruction, faster walking velocity, increased step velocity, longer step lengths, decreased step time, swing time, and double support time were found as well as larger trunk roll and pitch angles and angular velocities. (Shaw, et al., 2011). However, the exact opposite was reported for the ‘as fast as possible’ task constraint. These results provide further evidence for the benefit of skilled focused attention on gait in PD. Furthermore, individuals with PD may select a more cautious gait pattern strategy when temporal task constraints are present, ultimately prioritizing stability over the task goal (i.e., walk as fast as possible). This research provides evidence that when providing instructions to individuals with PD, task constraints need to be considered, as differing effects of instruction on gait performance may result. Specifically, it appears that the effect of instruction is limited depending on the temporal constraint (i.e., the speed in which the task is performed) encountered. Importantly, the notion of a task constraint is not confined to the speed at which the task is performed. Rather, task constraints also refer to the extension and/or alteration of the task itself. For example, instructions found to be beneficial during straight path walking may differ when used during turning, just as the modification of task speed resulted in differing conclusions (Shaw, et al., 2011). However, the literature to date has only evaluated the impairments in turning in PD.

1.2.6 Impaired Turning

Turning has been extensively evaluated in PD and can be considered a distinct task constraint. Postural instability in individuals with PD can be increased, depending on task constraints. For example, individuals with PD display reduced balance coupled with elevated falling occurrences while turning (Bloem, et al., 2001; Giladi, et al., 1992). Turning has also been associated with an increased chance of freezing (Giladi, et al., 1992; Johnell, Meltoa, Atkinson, O’Fallon, & Kurland, 1992). Hip and proximal femur fractures are also elevated in PD (Cumming & Klineberg, 1994; Johnell, et al., 1992). Potential reasons for this may be lateral instability and/or reduced use of compensatory arm reactions to aid in cushioning falls (Pressley, et al., 2003). Furthermore, the need to turn frequently during community ambulation has been previously described as a difficult task for individuals with PD (Stack & Ashburn, 1999; Stack, Ashburn, & Jupp, 2006; van Emmerick, Wagenaar, Winogradzka, & Wolters, 1999). This known difficulty in turning can present itself as a major problem as reports have suggested that at least two turns occur for every ten steps when performing simple daily activities (Sedgman & Goldie, 1994).

Turning is a challenging task as it involves the integration and coordination of many body segments (Stack, et al., 2006). Researchers have attributed the turning difficulty in PD to a number of causes. One possible cause is the well-documented dysfunctional basal ganglia (BG) associated with PD. In this view, successful turning and walking requires complex integration between multiple control mechanisms. These control mechanisms include neural commands sent to the lower limbs (to ensure cyclical motion; Hase & Stein, 1999; Orendurff, Segal, Berge, Flick, Spanier, & Klute, 2006; Patla, Adkin, & Ballard, 1999; Vaugoyeau, Viallet, Mesure, & Massion, 2003), controlled rotation of axial segments to enable appropriate adjustments required to attain a new travel path (Imai, Moore, Raphan, & Cohen, 2001; Patla, Prentice, Robinson, & Neufeld, 1991), and regulation of anticipatory gaze toward the newly acquired travel path (Hollands, Patla, & Vickers, 2002). The integration of these components is highlighted by the fact that when individuals turn in a preferred direction, asymmetric BG and related neural structures activity appear to coincide (Bracha, Shults, Glick, & Klienman, 1987; Mohr, Landis, Bracha, Fathi, & Brugger, 2003). This may suggest a close link between the BG and turning and may provide a possible explanation for reduced turning performance in PD. In addition, studies continually report difficulty turning as a main motor symptom of PD (Bloem, et al., 2001; Nieuwboer, De Weerdt, Dom, & Lasaffre, 1998; Stack, et al., 2006) coupled with severe gait-timing variability (Willems, et al., 2007). This provides further support for a dysfunctional BG having some type of effect on impaired turning. Previous research has suggested that simply instructing individuals with PD to focus attention on specific elements of the task may result in bypassing the defective BG circuitry, thus activating other intact brain structures (Morris, et al., 1995). However, this intervention has only been conducted during straight path walking (i.e., refer to section 1.2.5). The findings suggest a normalized gait pattern following the manipulation of the individual's cognitive strategy (Iansek, et al., 1995). With the new focus on functionally relevant studies in PD, it appears imperative to determine if these findings extend to tasks such as turning.

A second potential contributor to turning difficulties in PD is bradykinesia. Bradykinesia may be used as a compensatory strategy to limit postural instability during turns as coordination between all components of the task are demanding (Hase & Stein, 1999; Morris, et al., 2001; Schaafsma, et al., 2003; Vaugoyeau, et al., 2003). The simple act of revising the current walking pattern to initiate axial rotations from the head down to the lower limbs to accommodate a change in travel direction (i.e., forward to lateral path) is an intricate task (Mak, Patla, & Hui-Chan, 2008). The complexity of the task itself can be one reason for the typical slowing of movements, increasing the time to initiate, conduct, and complete the respective turn (Mak, et al., 2008).

Another compensatory turning strategy commonly used in individuals with PD is the "en-bloc" strategy (Stack, Jupp, & Ashburn, 2004; Visser, et al., 2007). This strategy is characterized by a coupling of the head, shoulder girdle, trunk, and lower limbs in unison, while completing a turn. This is in contrast to the typical cranial to caudal order typically observed in healthy individuals (Hollands, et al., 2002; Patla, et al., 1999). A typical cranial to caudal order when turning consists of orienting one's head to the new travel path, followed by rotation of the shoulders, trunk and pelvis, and lastly the lower limbs (Hollands, et al., 2002; Patla, et al., 1999). This 'en-bloc' turning strategy has been described as occurring as a result of axial rigidity (Crenna, et al., 2007; van der Berg, et al., 2006). Furthermore, reduced flexibility of the trunk has been described as another potential consequence of axial rigidity (Schenkman, Morey, & Kuchibhatla, 2000). The en-bloc strategy may be appropriate in certain circumstances. However, in order to initiate a successful change in direction, adequate rotational forces need to be executed at the trunk. The slowness and blocking of movement during the en-bloc strategy does not address the underlying impairment of axial rigidity. Instructional cues and/or attention focus may be a valid form of therapy to reorganize priorities for turning in individuals with PD.

Previous research has only described the impairments in turning in individuals with PD. This research has established that individuals with PD take a longer time (Behrman, et al., 1998; Crenna, et al., 2007; Mak, et al., 2008; Schenkman, et al., 2000; Stack & Ashburn, 2008; Stack, et al., 2006; Vaugoyeau, et al., 2003; Visser, et al., 2007; Willems, et al., 2007), require additional steps (Crenna, et al., 2007; Morris, et al., 2001; Schenkman, et al., 2000; Stack & Ashburn, 2008; Stack, et al., 2006; Willems, et al., 2007) and utilize a narrow stance width and smaller length between strides (Gruendlinger, et al., 2005; Mak, Chan, & Patla, 2005; Mak, et al., 2008; Morris, et al., 2001; Stack, et al., 2006; Vaugoyeau, et al., 2003; Willems, et al., 2007) when completing a turn. Furthermore, decreased turning velocities (Gruendlinger, et al., 2005; Mak, et al., 2005; Vaugoyeau, et al., 2003; Visser, et al., 2007) and horizontal ground reaction forces (Vaugoyeau, et al., 2003) have been reported as well. The impairments appear independent of turn type difficulty as studies have evaluated turning angles of 30 degrees (Mak, et al., 2008; Morris, et al., 2001), 45 degrees (Vaugoyeau, et al., 2003), 60 degrees (Mak, et al., 2008; Morris, et al., 2001), 90 degrees (Crenna, et al., 2007; Morris, et al., 2001), 120 degrees (Morris, et al., 2001), 180 degrees (Stack & Ashburn, 2008; Stack, et al., 2006; Visser, et al., 2007; Willems, et al., 2007), and 360 degrees (Schenkman, et al., 2000).

In addition to changes in typical gait parameters, Visser and colleagues (2007) conducted a study evaluating a new method to quantify walking and turning in PD. The research was conducted using a device that measured angular velocity of the trunk in both the yaw and roll planes (SwayStar system, Balance Int. Innovations GmbH, Switzerland). The task required participants to walk 6 meters at their comfortable speed, turn 180 degrees and walk back. This was to be completed under four different turning tasks, completed in a pseudo-random order. The four tasks consisted of ‘normal turning’ (i.e., self-paced turning), ‘rapid turning’ (i.e., turning as fast as possible), ‘cued turning’ (i.e., turning to an auditory cue at a pseudo-random distance), and ‘dual tasking’ (i.e., turning while answering pre-defined simple questions). Importantly, for each trial, the start and end of the turn was marked by an investigator by viewing the yaw displacement trace (Visser, et al., 2007). Additionally, two second straight path walking episodes were marked before and after normal turns to determine yaw and roll angular velocities during walking.

The results of the study showed that PD patients took significantly longer to turn compared to healthy controls, and peak angular yaw and roll velocities were reduced for all four turning tasks (Visser, et al., 2007). The authors concluded that the use of this device appears to be a feasible method for objectively quantifying turning movements in PD. Furthermore, the use of this device provides additional benefits for evaluating the act of turning as the device is placed at the lower back and "is in direct relation to stability of the trunk, which is relevant for maintaining overall balance" (Visser, et al., 2007). Therefore, it appears that quantifying turning through peak angular yaw and roll velocities may be a viable means for testing whether skilled verbal instructions can extend to the task of turning.

1.2.7 Lead-up to Research

The most devasting motor symptom of PD, postural instability, appears to be non-responsive to pharmacotherapy. Novel studies need to start focusing on valid ways to counteract this issue of postural instability, as falling is a major issue in this population. It is known that numerous studies have been conducted evaluating the benefit of external attention focus instructions. Almost all of these studies have suggested that an external focus of attention generates the best results in terms of performance, regardless of task. However, some reports have stated that an internal focus of attention results in performance enhancements but is perhaps task specific (Canning, 2005).

For individuals with PD, the notion of internal or external attention focus does not matter. What matters is the fact that instruction can result in improved performance. To date, no study has been conducted on evaluating instructions on turning in PD. Turning is a requirement of completing ADLs and more research is needed, as turning requires different coordination compared to rudimentary straight path walking. Furthermore, previous studies have reported normative straight path walking values in individuals with PD while severe turning abnormalities exist (Crenna, et al., 2007; Visser, et al., 2007). Keeping in-line with previous findings, we will ask the question does instructing individuals with PD to focus on certain aspects of turning equate to improved turning performance in PD?

CHAPTER TWO: Rationale, Purpose, Research Questions and Hypotheses

2.1 Rationale

Difficulty when executing turns is a common problem for individuals with PD. Research has shown that individuals with PD take longer to complete a turn, take additional steps, and utilize a narrow stance width and length between strides when completing a turn (Behrman, et al., 1998; Crenna, et al., 2007; Gruendlinger, et al., 2005; Mak, et al., 2005; Mak, et al., 2008; Morris, et al., 2001; Schenkman, et al., 2000; Stack & Ashburn, 2008; Stack, et al., 2006; Vaugoyeau, et al., 2003; Visser, et al., 2007; Willems, et al., 2007). These deficits in turning capabilities may contribute to more falls when turning in individuals with PD.

Instruction has been previously used to improve performance on straight path walking tasks. These studies have focused on amplitude-based (i.e., take big steps) instructions to counteract the bradykinesia typically observed in PD. Significant improvements have been found in stride length, gait velocity, and double support duration. The benefits associated with instructional sets have yet to be evaluated on tasks other than straight path walking. The use of skilled instructions may be a viable means of improving turning performance in individuals with PD as previous reports have found improvements in walking when provided with specific instruction. These improvements during normal walking can not be inferred to transfer to other tasks, such as turning, as task constraints (i.e., temporal constraint) have been shown to alter the benefits of verbal instructions (Shaw, et al., 2011).

2.2 Purpose

The primary purpose of this study was to examine the effectiveness of different verbal instructions compared to no instruction on walking and turning performance in PD. The verbal instructional sets used were to focus on “take big steps”, “make larger movements of your trunk”, and “focus on the end point and/or turn point” (Table 1). The first two sets were internally based with the last set considered externally based.

2.3 Research Questions

1) Do the instructions to “take big steps”, “focus on the end point and/or turn point” (i.e., previously used instructions) and/or “make larger movements of your trunk” (i.e., novel instruction) improve performance (i.e., increases in trunk sway and reductions in time needed to complete the task) of normal walking and turning in individual with PD?

2.4 Hypotheses

It was hypothesized that providing simple verbal instructions that direct attention towards the feet (Baker, et al., 2007; Behrman, et al., 1998; Canning, 2005; Lehman, et al., 2005; Morris, et al., 1998; Shaw, et al., 2011; Werner, et al., 2003), the trunk (Visser, et al., 2007), or an external source (Landers, et al., 2005; Wulf, et al., 2009) compared to no instructions at all would result in improved walking and turning performance as shown by increased trunk sway measures and reduced duration measures.

CHAPTER THREE: Methodology

3.1 Participants

Twelve individuals diagnosed with idiopathic PD volunteered to participate in this study. All participants were recruited from the Niagara Region using posters, word of mouth, and advertisement at a support group for PD. Participants were excluded from participating in the study if they self-reported any type of balance or gait impairment that was not related to PD (i.e., musculoskeletal, sensory, and/or neurological deficits). Participants who scored less than or equal to 24 out of 30 on the Mini Mental State Examination (MMSE) and/or greater than 4 out of 5 on the modified Hoehn & Yahr scale were also excluded from participating in the study. All experimental procedures were approved by the Brock University Bioscience Research Ethics Board (File #11-152). All participants, informed of the experimental procedures, provided written consent prior to the start of the study.

3.2 Procedures

All of the experimental procedures were conducted with the participant in a self-described best "on" anti-parkinson medication state. This decision was based on previous research that turning deficits and falls are often observed when individuals with PD are "on" their medication (Ashburn, et al., 2001; Bloem, et al., 1996; Bloem, et al., 2001; Crenna, et al., 2007; Hou, et al., 2008).

3.2.1 Clinical Assessment

First, all participants completed the MMSE to determine cognitive status (Appendix A; Folstein, Folstein, & McHugh, 1975). Second, participants were assessed on the modified Hoehn and Yahr scale (Appendix B; Hoehn & Yahr, 1967) as a general indicator of disease severity. If participants scored less than or equal to 24 out of 30 on the MMSE and/or greater than 4 out of 5 on the modified Hoehn & Yahr scale, they were excluded from further participation in the study. Third, participants were evaluated on the motor component (Part III) of the Unified Parkinson Disease Rating Scale (UPDRS) to provide a measure of disease severity related to the motor symptoms associated with PD (Appendix C; Richards, Marder, Cote, & Mayeux, 1994). Fourth, demographic measures of age and sex, and anthropometric measures of height and weight were obtained from each participant.

Following these initial three assessments, participants then completed a questionnaire package with the questionnaires listed below presented in a random order.

The Activities-specific Balance Confidence Scale (ABC) was included to assess balance confidence when completing ADLs (Appendix D; Powell & Myers, 1995). The questionnaire includes 16 activities ranging from walking around the house, to standing on a chair to reach for an object, to walking on an icy sidewalk. For this scale, participants reported their confidence in being able to avoid a loss of balance when performing each of the 16 activities on a scale from 0% (no confidence) to 100% (complete confidence). The mean ABC score for all 16 items was calculated (ABC-16; Powell & Myers, 1995). In addition, a mean score for 6 of the most challenging items was calculated (ABC-6; Peretz, Herman, Hausdorff, & Giladi, 2006). These six items were reach forward on tiptoes, stand on chair to reach object, walk in a crowd and bumped in to, ride escalator holding rail, ride escalator not holding rail, and walk on icy sidewalk (Appendix D).

The Ambulatory Self-Confidence Questionnaire (ASCQ) was included to measure confidence during walking tasks (Appendix E; Asano, Miller, & Eng, 2007). This questionnaire includes 22 activities ranging from stepping up onto a curb to walking on a moving bus. For each activity, individuals reported on a scale from 0 (not at all confident) to 10 (extremely confident) their confidence in being able to avoid falling while performing the activity. The mean ASCQ score for all 22 items was calculated.

The Movement Specific Reinvestment Scale (MSRS) was included to determine the tendency for individuals to reinvest or consciously control their movements (Appendix F, Masters, et al., 2007). This 10 item questionnaire includes two subscales evaluating movement self-consciousness (MSC; 5 items) and conscious motor processing (CMP; 5 items). The MSC subscale determines whether participants are worried or concerned about their "style" of moving whereas the CMP subscale determines whether participants are worried about controlling the mechanics of their movement. Participants provided an indication to what extent each statement described them using a 6-point Likert scale ranging from *strongly disagree* to *strongly agree*. A sum score for the 10 items was calculated (range from 10 to 60). As well, for each subscale, items were summed to produce a score for CMP (range from 5 to 30) and MSC (range from 5 to 30).

The New Freezing Of Gait-Questionnaire (NFOG-Q) was used to provide an assessment of when and where freezing episodes, if any, typically occur (Appendix G; Nieuwboer, et al., 2009). The questionnaire is divided into three parts. Part 1 (1 item) is used to determine if freezing episodes have been experienced over the past month. If no freezing episodes were reported, the participant was classified as a "non-freezer" and the questionnaire was complete. However, if freezing episodes were reported, part 2 (4 items) was completed to determine the severity of the freezing and part 3 (3 items) was completed to determine the impact of the freezing episodes on daily life.

Participants were also asked several other questions related to their PD. Participants reported the time that had elapsed since first being diagnosed with PD by a neurologist, as well as the anti-parkinson medications they were currently taking to manage their symptoms. Participants were also asked to report whether they experienced difficulties performing activities of daily living that require some form of turning. The number of falls each participant had experienced in the last six months was also reported, where a fall was defined as, “any unexpected event that caused the person to unintentionally land on any lower surface (e.g., object, floor, or ground), regardless of any sustained injury (Bloem, et al., 2001).

After completing the questionnaire package, participants then performed three functional assessments. The Timed-Up-and-Go (TUG) test was used to assess functional mobility (Morris, Morris, & Iansek, 2001). Participants were required to stand up from a chair, walk a distance of three meters, turn around and sit back down. Time to complete the task was measured in seconds with a stopwatch from the word “go” to when the participant had completely sat back down into the chair. Three trials were performed; the average time for the three trials was calculated for each participant. The Flexometer test was used to measure trunk flexibility (Appendix H; Richards, et al., 1994). Participants were required to stand with feet shoulder width apart while facing away from the wall on which the flexometer was positioned. The height of the flexometer was adjustable and it was placed at shoulder height for each participant. Participants, keeping their feet stationary, were told to extend their arm, make a fist, and rotate their arm backward in order to push the bar on the flexometer as far as possible. The distance the bar on the flexometer traveled was recorded in inches. Three trials for each arm were completed with the best trial for each arm used. The Functional Reach test (FR) was used to assess stability limits in the forward direction (Appendix I; Duncan, Weiner, Chandler, & Studenski, 1990). Participants were required to stand with their feet shoulder width apart and parallel to a wall. Participants were then asked to extend their arm and make a fist. A meter stick, placed at the right acromion height and parallel to the end of the right third metacarpal, was secured to the wall. Participants were then asked to reach as far forward as they could comfortably without a loss of balance and/or taking a step. The upper extremity was not allowed to come into contact with the wall. The distance from the start to end position of the hand was measured in inches. Three trials were performed with the best of three trials used.

3.2.2 Walking Tasks

Participants were required to perform a straight path walking task and a straight path walking task with a 180° turn. The straight path walking task is referred to as the normal walk task while the straight path walking task with a 180° turn is referred to as the 180° turn task.

The normal walk task had the participant walk a straight and wide path for a distance of six meters. The start and end of the path were marked with tape on the floor. The participant was instructed to start from a standing position, walk at his/her preferred pace, and come to a two-footed stop at the end of the path. The 180° turn task used the same marked path. However, for this task, the participant was instructed to walk the six meter path, turn 180° around once he/she had completely crossed the tape that marked the end of the path, and walk back and come to a two-footed stop at the initial start position. No restriction was placed for turn direction allowing each participant to naturally select and implement a 180° turn. Again for this task, the participant was instructed to walk at his/her preferred pace.

Throughout the normal walk task and 180° turn task, the participant was required to wear a light-weight device that was mounted to his/her lower back (L2-L3) via an elasticized belt (SwayStar system, Balance Int. Innovations GmbH, Switzerland). This device was used to provide an estimate of trunk control during the performance of these tasks. The time to complete the tasks was also recorded with a standard stopwatch.

3.2.3 Instruction Conditions

The normal walk and 180° turn tasks were performed under four different instruction conditions. The instruction conditions were 1) no instruction (i.e., baseline), 2) feet instruction, 3) trunk instruction, and 4) external instruction. Thus, participants experienced a total of 24 trials; three trials for each walk/turn task and instruction condition were performed.

Participants always performed the no instruction condition first to provide a baseline condition that would not be influenced by potential carry-over effects from the other instruction conditions (i.e., feet, trunk, or external instructions). This approach has been used in previous studies (Baker, et al., 2007; Werner & Gentile, 2003). Participants performed this no instruction condition with no additional instructions other than to walk at their preferred pace (Table 1). There was a random presentation of the normal walk and 180° turn task to each participant in this no instruction condition. Following the completion of the no instruction condition, the participant answered the following question: “Was there anything within your own body and/or environment that you were thinking about when performing the task?” This question was asked immediately after the completion of the normal walk or 180° turn task to determine if the participant preferred to focus on something specific when performing each of these tasks.

The no instruction or baseline condition was followed by a randomized block presentation of the remaining instruction conditions. Instruction condition was blocked and within this block the normal walk and 180° turn tasks were randomly presented to participants. Therefore, for a specific instruction condition, both the normal walk and 180° turn tasks were completed within that condition before moving to the next instruction condition.

In addition to the standard instructions that were given for the normal walk and 180° turn tasks, specific instructions were provided to each participant according to the task and instruction condition being completed (Table 1). The “focus on taking big steps” and “focus on the end point” instructions were chosen as they coincided with previous research evaluating the efficacy of providing both internal and external based instructions. The novel trunk based instruction “focus on making larger movements of your trunk” was chosen in an attempt to see if a reduction in axial rigidity would occur with simple verbal instructions directed towards increasing trunk movement. More specifically, this instruction was chosen in an attempt to improve turning abilities in PD participants as previous authors have reported reduced yaw velocities while conducting 180° turns (Visser, et al., 2007). This may provide evidence for the importance of the trunk during activities requiring turning.

A manipulation check was conducted after each task and instruction condition to determine how focused the participants were to adhering to the instructions provided. Participants were required to answer the following question: "On a scale of 0 to 100%, with 0% representing not at all focused and 100% representing completely focused, how focused were you in adhering to the instructions provided to you for the task?" This question was used to determine whether or not the participants had focused on the prescribed instruction and/or whether they may have been focusing on other cues within their body or the environment. The experimenter also noted any questions and/or confusion regarding the instructions for a given task.

Throughout all trials, participants received reminder instructions prior to each trial to clarify the instructions that were to be followed for that particular trial.

Table 1. The content of the instructions (in addition to the standard instruction) provided for each instruction condition for the normal walk and 180° turn task.

	Normal Walk	**180° turn**
Standard Instruction	Walk at your normal pace and come to a 2-footed stop at the end	Walk at your normal pace and once at the tape, turn around and walk back to the start position coming to a 2-footed stop
Baseline	No Additional Instruction	No Additional Instruction
Feet	Focus on taking big steps	Focus on taking big steps while walking towards the turn, during the turn, and while returning back to the start
Trunk	Focus on making larger movements of your trunk	Focus on making larger movements of your trunk while walking towards the turn, during the turn, and while returning back to the start
External	Focus on the end point	Focus on the end point while walking towards the turn, the turn point while turning, and the end point while walking back to the start position

3.3 Dependent Measures

Balance during the normal walk and 180° turn task was estimated by recording trunk movements using angular velocity transducers (SwayStar System, Balance Int Innovations GmbH, Switzerland). Participants wore the lightweight device which was attached to an elasticized belt and placed on the lower back at the lumbar level of L2-L3. The device recorded trunk movements in both yaw (i.e., rotation) and roll (i.e., side-to-side) directions during the tasks. The device uses two digitally-based angular-velocity transducers, oriented so that one transducer measures angular velocity deviations in the yaw direction and the other angular velocity deviations in the roll direction. Peak-to-peak range excursions in yaw and roll directions for both trunk angular displacement (i.e., with respect to reset angular positions of zero displacement at the start of each trial) and trunk angular velocity were calculated. Both roll and yaw angles were calculated via the SwayStar system using angular velocities. Thus, four dependent measures were used to estimate balance during the tasks: trunk yaw angle, trunk yaw velocity, trunk roll angle, and trunk roll velocity. Task duration was also recorded. The interval over which these dependent measures were captured differed for the normal walk and 180° turn task.

For the normal walk task, yaw angle, yaw velocity, roll angle, and roll velocity were calculated over a two second interval that was identified by the experimenter in the middle of each trial (Visser, et al., 2007; Figure 1). Duration for this task was determined for the interval between the start and end of the path using a stopwatch. For the 180° turn task, two separate intervals were examined based on the work of Visser and colleagues (2007). These two intervals were 1) the approach to the turn, and 2) the turn itself. For the approach to the turn, a two second interval was marked during the six meter approach to the turn (Figure 2). Yaw angle, yaw velocity, roll angle, roll velocity values were determined over this selected interval. For the turn, the start and end of the turn was determined by visually inspecting and marking the initial yaw displacement deviation and marking the plateau in the yaw displacement profile (Visser et al., 2007; Figure 2). For this time interval, yaw angle, yaw velocity, roll angle, roll velocity, and turn duration were calculated.

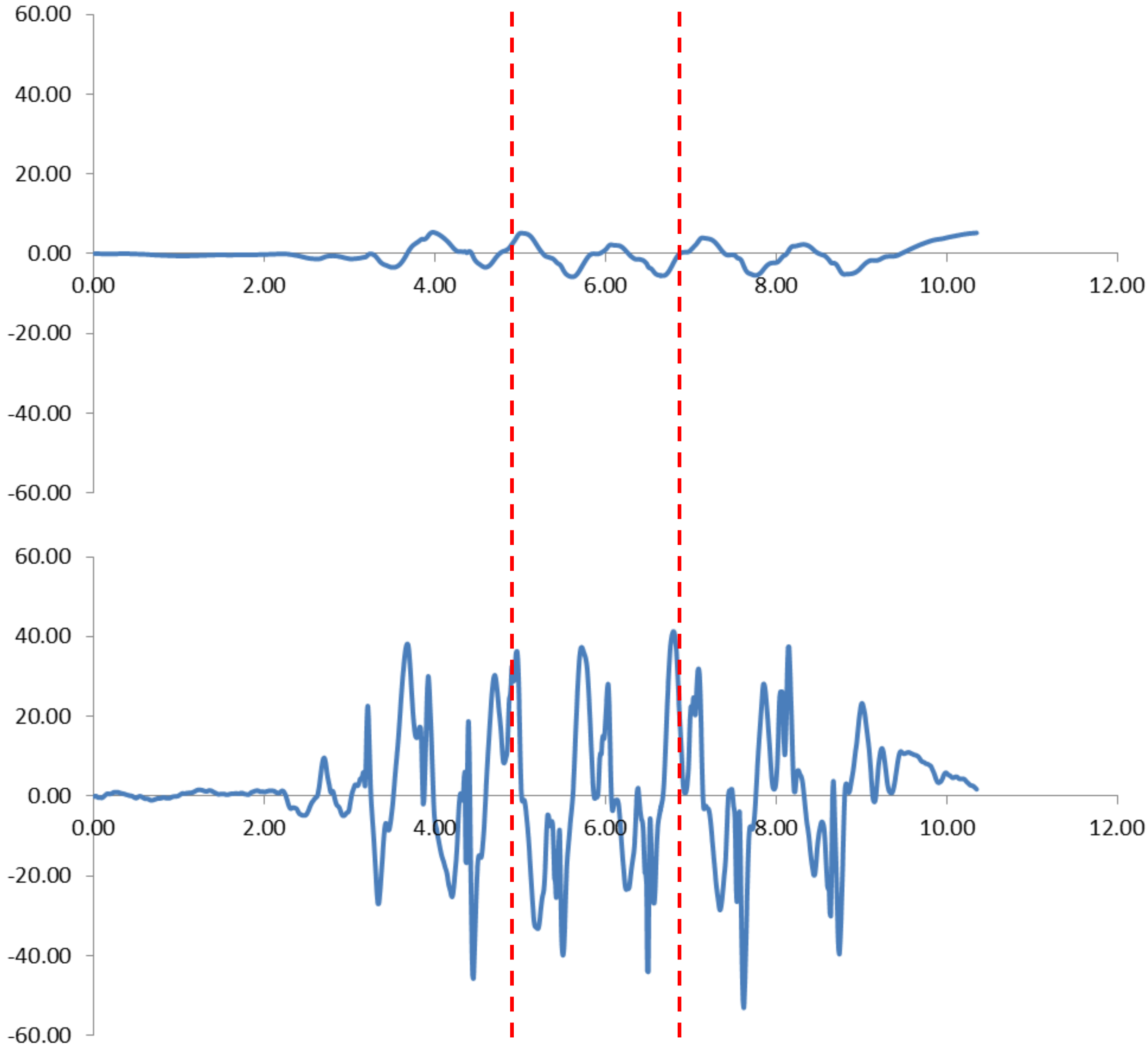

Figure 1. Representative profile of yaw angle in degrees (upper panel) and yaw velocity in degrees per second (lower panel) during the normal walk task for a single participant. The dashed lines represent the start and end of the analyzed area (approximately 2 seconds).

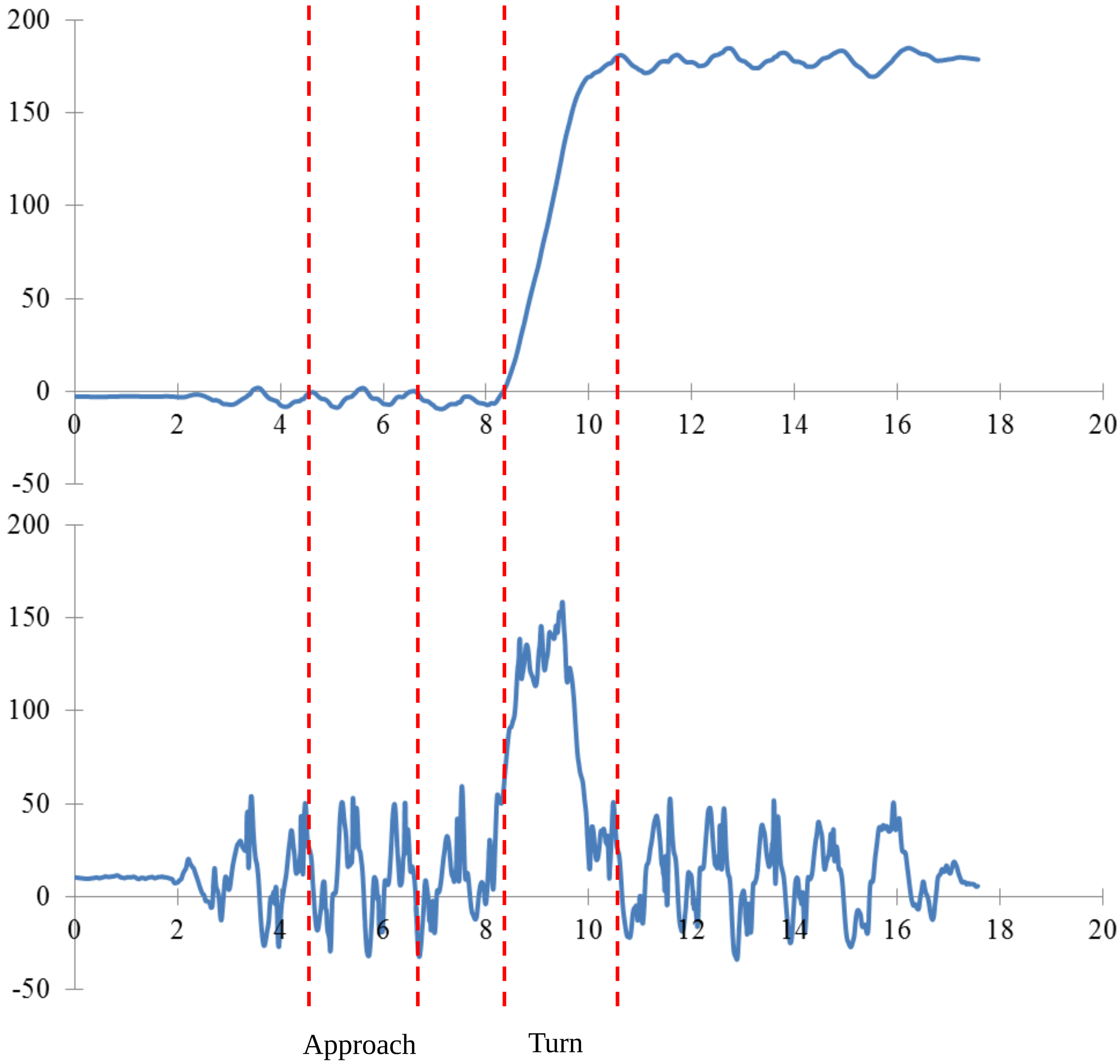

Figure 2. Representative profile of yaw angle in degrees (upper panel) and yaw velocity in degrees per second (lower panel) during the 180° turn task for a single participant. The dashed lines represent the approach and turn phases during which trunk sway dependent measures were calculated.

3.4 Statistical Analysis

Means and standard deviation values (or frequency measures where appropriate) were calculated for all clinical assessment measures to provide a description of the sample.

Means and standard error of the mean values were calculated for trunk sway and task duration measures by instruction, trial, and instruction by trial. To determine if the assumption of normal distribution was met, skewness and kurtosis were examined, and outliers were screened for all dependent measures by instruction condition. Significance was determined by dividing the skewness or kurtosis statistic by the standard error of the skewness or kurtosis statistic. Normality was met for most dependent measures and the decision was made to not transform the data as it was thought that the interpretation of the data may be hindered (Tabachnick & Fidell, 2007). Univariate outliers were identified using standardized z-scores. Z-scores greater than +/- 3.29 (p<0.001) were considered as an outlier. The assumption of sphericity was assessed using the Mauchly's test for each dependent measure. Dependent measures that violated the Mauchly's sphericity assumption ($p < 0.05$) were corrected using the Huynh-Feldt correction. Unless stated, the assumption of sphericity was met.

For the normal walk task, a 4 (instruction) x 3 (trial) repeated measures analysis of variance (ANOVA) procedure was performed for yaw angle, yaw velocity, roll angle, roll velocity over the defined 2 s time window, and total task duration. For the 180° turn task, the approach to the turn and turn phase were examined separately. For the approach to the turn phase, a 4 (instruction) x 3 (trial) repeated measures analysis of variance (ANOVA) procedure was performed for yaw angle, yaw velocity, roll angle, and roll velocity. Duration was not examined as trunk sway measures were examined only during an interval that was set to two seconds for all participants and all trials. For the turn phase, a 4 (instruction) x 3 (trial) repeated measures analysis of variance (ANOVA) procedure was performed for yaw angle, yaw velocity, roll angle, roll velocity, and turn duration.

For all analyses, for any significant main effects of instruction and trial, comparisons, between instruction conditions or trials, using a Bonferroni correction, were conducted. The level of significance was set at $p < 0.05$ for all analyses. All statistical calculations were conducted using commercially available software (SPSS, Chicago, IL, USA).

CHAPTER FOUR: Results

4.1 Data Screening

4.1.1 Outliers

A total of 16 participants were tested. Of these 16 participants, four did not meet the exclusion criteria. Therefore, a total of 12 participants were utilized during the data analysis. In addition, two of the 12 participants were removed for the normal walk task analysis based on self-reported confusion during the execution of both the 'feet' and 'trunk' instruction conditions (i.e., participant 6 and 11). This resulted in a data set of 10 participants for the normal walk task and 12 participants for the 180° turn task.

Variables were screened for univariate outliers for each instruction condition. Univariate outliers were identified using standardized scores (z-scores). A z-score greater than or equal to +/-3.29 was identified as an outlier. No outliers were found for the variables screened for each instruction condition.

4.1.2 Normality

Each dependent variable for each instruction condition was screened for normality by examining skewness and kurtosis values. Significance was determined by dividing the skewness and kurtosis statistic by the standard error of the skewness or kurtosis statistic. Tables 2, 3, and 4 display the skewness and kurtosis values for all dependent variables. For the normal walk task feet instruction yaw angle, trunk instruction roll angle and velocity, and external instruction yaw angle were significantly skewed. Feet instruction yaw angle, trunk instruction roll angle and velocity, and external instruction yaw angle were significantly kurtotic. For the approach to the turn phase no instruction roll velocity and yaw angle, feet instruction yaw angle, trunk instruction yaw angle, and external instruction roll velocity were significantly skewed. No instruction roll velocity and yaw angle, feet instruction yaw angle, and trunk instruction yaw angle were significantly kurtotic. For the turn phase of the 180° turn task no instruction roll angle and external instruction roll velocity were significantly skewed. No instruction roll angle was found to be significantly kurtotic.

Table 2. Skewness and kurtosis values for all dependent measures for the baseline, feet, trunk, and external instruction conditions for normal walk task. Standard error for skewness was 0.427 while the standard error for kurtosis was 0.833. Values greater than +/-3.29 represent significant skewness or kurtosis at $p < 0.001$ and are marked with an astrix.

Normal Walk								
Dependent Measure	**Baseline**		**Feet**		**Trunk**		**External**	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Roll Angle	1.475	0.124	-0.639	0.026	4.564*	6.963*	0.829	0.516
Roll Velocity	2.653	1.516	0.178	-0.089	3.368*	4.205*	3.075	2.832
Yaw Angle	3.117	1.235	4.461*	4.371*	1.478	-0.609	4.611*	5.959*
Yaw Velocity	3.187	2.110	1.124	-0.730	2.506	1.246	1.787	0.533
Duration	0.037	-0.456	-0.906	-1.343	1.759	0.975	-2.590	0.754

Table 3. Skewness and kurtosis values for all dependent measures for the baseline, feet, trunk, and external instruction conditions for approach task. Standard error for skewness was 0.393 while the standard error for kurtosis was 0.768. Values greater than +/-3.29 represent significant skewness or kurtosis at p < 0.001 and are marked with an astrix.

Approach to the Turn								
Dependent Measure	**Baseline**		**Feet**		**Trunk**		**External**	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Roll Angle	1.875	1.025	1.450	-0.827	2.277	1.667	0.036	-0.225
Roll Velocity	4.107*	4.027*	1.244	2.382	2.417	1.901	3.328*	3.083
Yaw Angle	3.361*	4.322*	5.634*	9.293*	4.265*	5.421*	2.028	0.663
Yaw Velocity	1.611	0.152	2.089	1.249	3.198	2.685	2.008	0.549

Table 4. Skewness and kurtosis values for all dependent measures for the baseline, feet, trunk, and external instruction conditions for 180° turn task. Standard error for skewness was 0.393 while the standard error for kurtosis was 0.768. Values greater than +/-3.29 represent significant skewness or kurtosis at $p < 0.001$ and are marked with an astrix.

180° Turn								
Dependent Measure	**Baseline**		**Feet**		**Trunk**		**External**	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Roll Angle	4.303*	3.797*	0.585	-1.445	2.461	0.568	2.043	0.289
Roll Velocity	2.583	0.345	2.420	0.074	3.102	2.708	4.298*	3.755*
Yaw Angle	-0.880	1.525	1.634	2.021	-2.242	1.569	1.827	3.194
Yaw Velocity	0.906	-1.139	0.427	-0.043	-1.005	-0.969	-0.364	-0.499
Turn Duration	0.705	0.871	2.478	0.320	0.298	-1.505	0.407	-0.342

4.1.3 Sphericity

Sphericity among instruction conditions, trial, and instruction by trial interactions for each task and dependent variable were assessed using the Mauchly's test. Dependent measures that violated the Mauchly's sphericity assumption ($p < 0.05$) were corrected using the Huynh-Feldt correction. Unless stated, the assumption of sphericity was met.

4.2 Clinical Assessment

Table 5 presents individual and mean and standard deviation scores for the demographic and anthropometric characteristics of the 12 PD participants. The sample had an average age of 68.75+/-8.89 years, height of 171.2+/-10.70 centimeters, weight of 86.92+/-16.00 kilograms, a modified H&Y of 2.04+/-0.26, and a UPDRS of 42.83+/-9.90, respectively.

Table 6 presents the individual and mean and standard deviation scores for the self-reported questionnaires of the 12 PD participants. The sample had an average ABC score of 80.34+/-10.43%, an average ABC-6 score of 66.25+/-17.66%, and an average ASCQ score of 7.92+/-1.24. The sample appeared to think more about the processes of the movement (CMP – 16.08+/-7.05) compared to the 'style' of moving (MSC – 14.08+/-8.12). The data also portrays a PD sample in which 25% of individuals ($n = 3$) reported at least one freezing of gait episode within the past month. Furthermore, 41.67% of the participants reported difficulty in completing tasks that require some form of turning and 33.3% reported suffering from a fall in the past six months. Lastly, the average disease duration for this sample of PD patients was 6.17+/-3.69 years.

Table 7 presents the individual and mean and standard deviation scores for the functional measures completed by the 12 PD participants. For the TUG measure, participants required an average of 13.04+/-2.43 seconds to complete the task. For the trunk flexibility measures, individuals were able to rotate to each side approximately the same distance (Right:21.38+/-6.70 inches; Left:23.21+/-6.38 inches). On the FR test, participants were able to reach an average distance of 11.66+/-4.35 inches.

Table 5. Characteristics of PD participants. Individual scores and sample mean and standard deviation values are reported (MMSE=Mini-Mental State Examination; H & Y= Hoehn & Yahr; UPDRS= Unified Parkinson's Disease Rating Scale).

Participant	**2**	**3**	**4**	**5**	**6**	**8**	**10**	**11**	**12**	**15**	**16**	**18**	**Mean (SD)**
Age (y)	73	65	65	53	81	70	69	77	60	83	69	60	68.75 (8.89)
Gender	F	F	F	F	M	M	M	M	M	M	M	F	5 F / 7 M
Height (cm)	155.0	169.0	177.5	162.7	173.5	178.0	182.0	169.5	185.0	161.3	185.0	156.0	171.2 (10.70)
Weight (Kg)	76.7	85.8	98.7	87.0	77.7	128.8	90.9	72.3	91.4	70.18	73.18	90.36	86.92 (16.00)
MMSE	29	30	29	30	28	27	29	27	30	27	30	28	28.97 (1.23)
H & Y	2	2	2	1.5	2.5	2	2	2	2	2.5	2	2	2.04 (0.26)
UPDRS	34	44	37	24	50	50	48	46	27	52	52	50	42.83 (9.90)

Table 6. Self-report questionnaires completed by participants. Individual participant scores and sample mean and standard deviation values are reported. ABC= Activities-specific Balance Confidence scale; ABC-6= Activities-specific Balance Confidence scale calculated from 6 measures from ABC; ASCQ= Ambulatory Self Confidence Questionnaire; MSRS-T= Movement Specific Reinvestment Scale; MSC= Movement Self-Conscious subscale calculated from MSRS-T; CMP= Conscious Motor Processing subscale calculated from MSRS-T.

Participant	2	3	4	5	6	8	10	11	12	15	16	18	Mean (SD)
ABC (%)	66.2	73.1	91.9	78.8	84.4	76.3	93.1	91.3	89.4	62.5	85.3	71.9	80.34 (10.43)
ABC-6 (%)	48.3	65.0	78.3	65.0	71.7	60.0	83.3	88.3	82.5	31.7	77.5	43.3	66.25 (17.66)
ASCQ (0-10)	6.8	7.0	9.4	6.8	8.8	8.2	9.4	8.6	9.2	6.9	8.3	5.7	7.92 (1.24)
MSRS-T (10-60)	13	54	11	34	49	31	13	25	26	28	49	29	30.17 (14.46)
MSC (5-30)	5	25	5	15	24	16	6	13	10	9	29	12	14.08 (8.12)
CMP (5-30)	8	29	6	19	25	15	7	12	16	19	20	17	16.08 (7.05)
Freezer	No	Yes	No	Yes	No	No	No	Yes	No	No	No	No	3 Y / 9 N
Disease Duration (y)	8	1	6	2	7	5	3	8	10	2	9	13	6.17 (3.69)
Difficulty Turning	No	Yes	No	Yes	Yes	No	Yes	No	Yes	No	No	No	5 Y / 7 N
Falls in past 6 months	0	0	0	4	0	4	1	1	0	0	0	0	0.83 (1.53)
Medication intake (mins)	120	120	120	120	180	110	75	150	70	120	90	105	115.0 (30.08)

Table 7. Functional measures completed by participants. Individual scores and sample mean and standard deviation values are reported. TUG= Timed Up and Go test; TFL = Trunk Flexibility Right; TFR = Trunk Flexibility Left; FR = Functional Reach.

Participant	**2**	**3**	**4**	**5**	**6**	**8**	**10**	**11**	**12**	**15**	**16**	**18**	**Mean (SD)**
TUG (sec)	11.9	14.7	8.8	14.7	13.7	11.7	11.8	14.7	10.9	17.8	11.2	14.7	13.04 (2.43)
TFL (inches)	24.8	8.0	23.0	31.0	17.5	34.0	24.0	24.0	24.0	22.3	24.0	22.0	23.21 (6.38)
TFR (inches)	26.2	11.0	20.0	24.3	18.5	33.0	29.0	21.0	25.0	10.5	21.0	17.0	21.38 (6.70)
FR (inches)	11.2	6.6	12.6	13.0	9.8	13.8	5.3	12.0	18.9	6.5	18.9	11.2	11.66 (4.35)

4.3 Effect of Instruction on Trunk sway and Duration measures

A summary of the results of the repeated measures ANOVA procedures that were conducted for each dependent variable for the normal walk and approach to the turn and turn phases of the 180° turn task are presented in Table 8 to Table 10.

4.3.1 Normal Walk

4.3.1.1 Yaw Angle and Velocity

Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of instruction on yaw velocity ($\chi^2(5) = 13.83$, $p < .05$). Therefore, the degrees of freedom were corrected using the Huynh-Feldt estimates of sphericity ($\varepsilon = 0.57$). With this correction, there was an instruction main effect observed for yaw angle ($F_{(3,27)}=3.953$; $p=0.019$). Although it appeared that the feet instruction condition generated larger yaw angle values compared to the no instruction condition, the follow-up, Bonferroni corrected, comparisons did not reveal significant differences between the instruction conditions for yaw angle (Figure 3A). The trial main effect and instruction-by-trial interaction effect was not significant for yaw angle. No significant main effects or interaction effect was observed for yaw velocity.

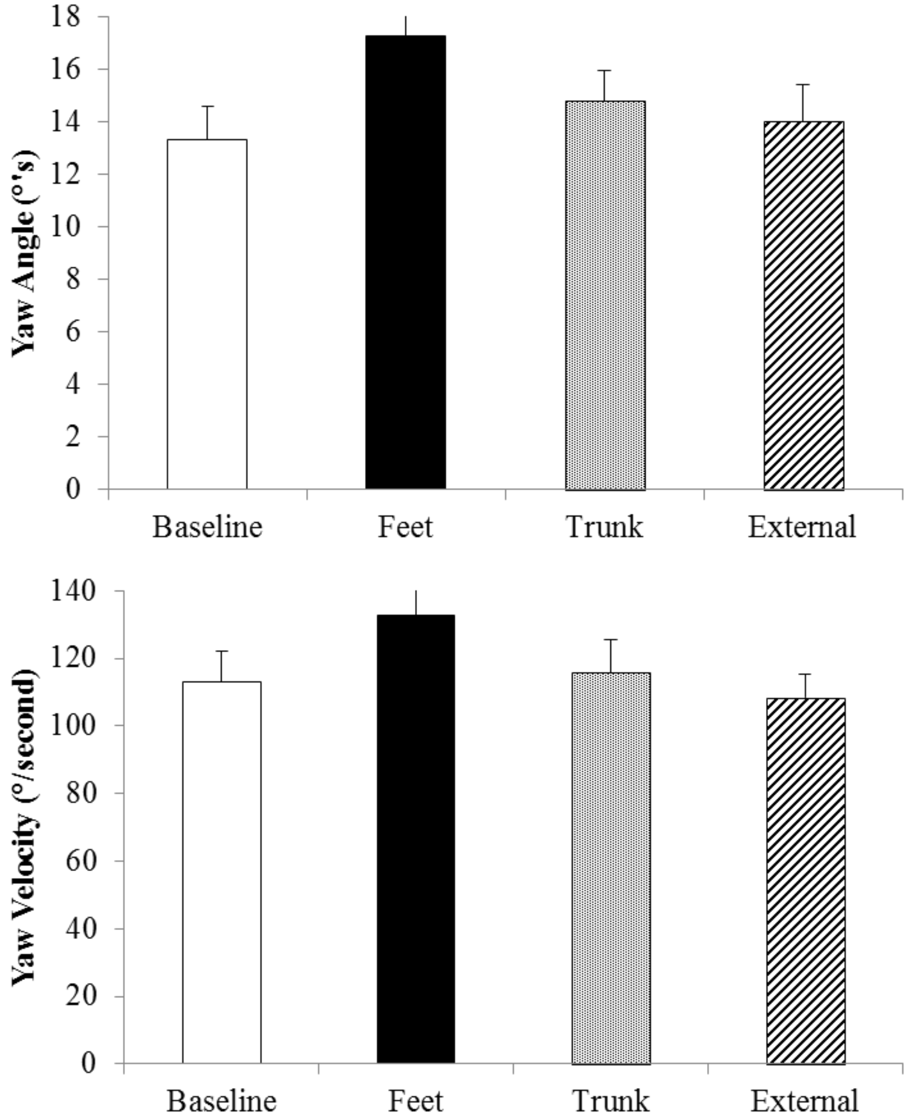

Figure 3. Effects of instruction condition on A) yaw angle (no differences; $p>0.05$), and B) yaw velocity (no differences; $p>0.05$). Error bars represent standard error of the mean.

4.3.1.2 Roll Angle and Velocity

An instruction main effect was observed for roll angle ($F_{3,27}$=5.837; p=0.003). Roll angle was significantly larger for the feet instruction condition compared to the no instruction condition (p=0.038) and the external instruction condition (p=0.001; Figure 4A). The trial main effect and instruction-by-trial interaction effect for roll angle were not significant.

Only a trial main effect was observed for roll velocity ($F_{2,18}$=3.956; p=0.038). Although it appeared that the feet instruction condition generated larger roll velocities in trial 2 compared to trial 1, the follow-up, Bonferroni corrected, comparisons did not reveal significant differences between trials. No instruction main effect or instruction-by-trial interaction effects were observed for roll velocity.

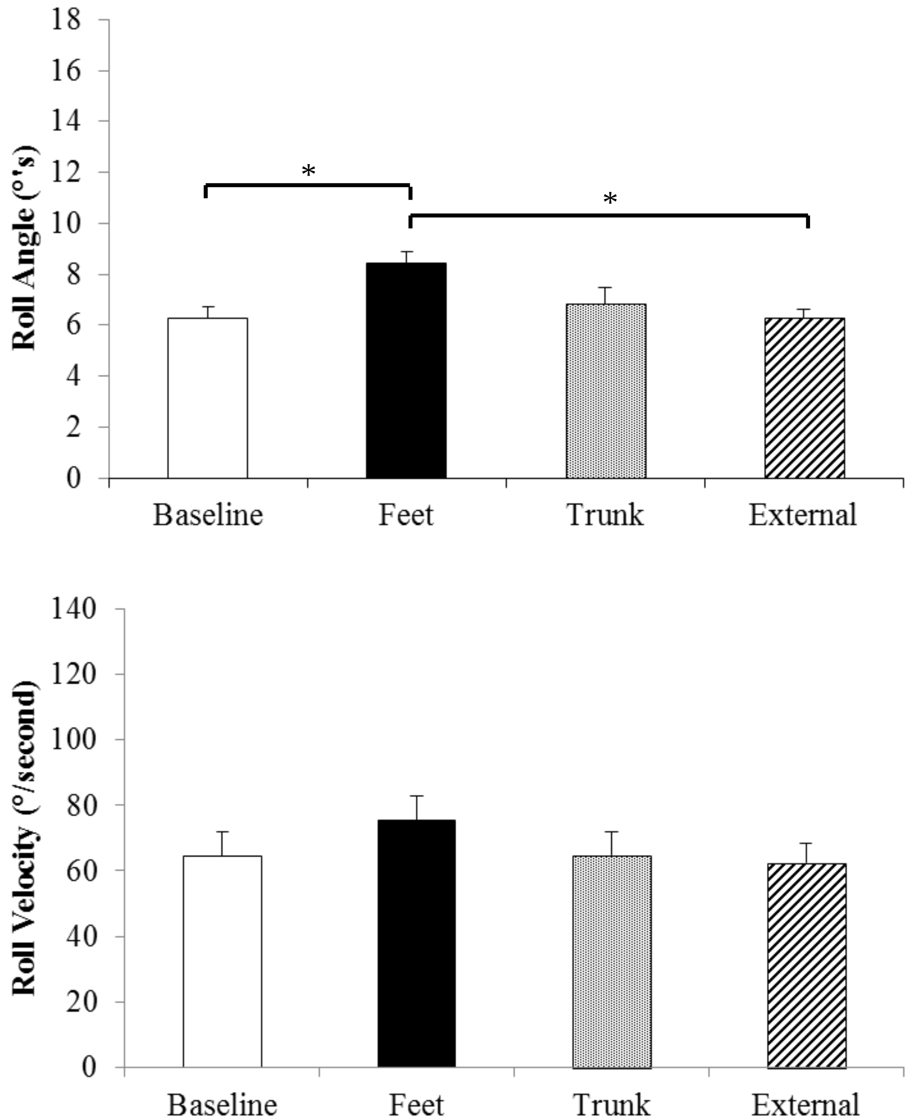

Figure 4. Effects of instruction condition on A) roll angle (feet > baseline $p = 0.038$ and external $p = 0.001$), and B) roll velocity (no difference; $p>0.05$). Error bars represent standard error of the mean.

4.3.1.3 Task Duration

There was an instruction main effect for task duration ($F_{3,27}$=5.985; p=0.003). The task was completed faster for the feet instruction condition compared to the no instruction condition (p=0.013; Figure 5). A trial main effect was also observed for task duration ($F_{2,18}$=3.912; p=0.039). Although it appeared that longer durations occurred in trial 1 compared to trial 3, the follow-up, Bonferroni corrected, comparisons did not reveal significant differences between trials. No instruction-by-trial interaction effect was observed for task duration.

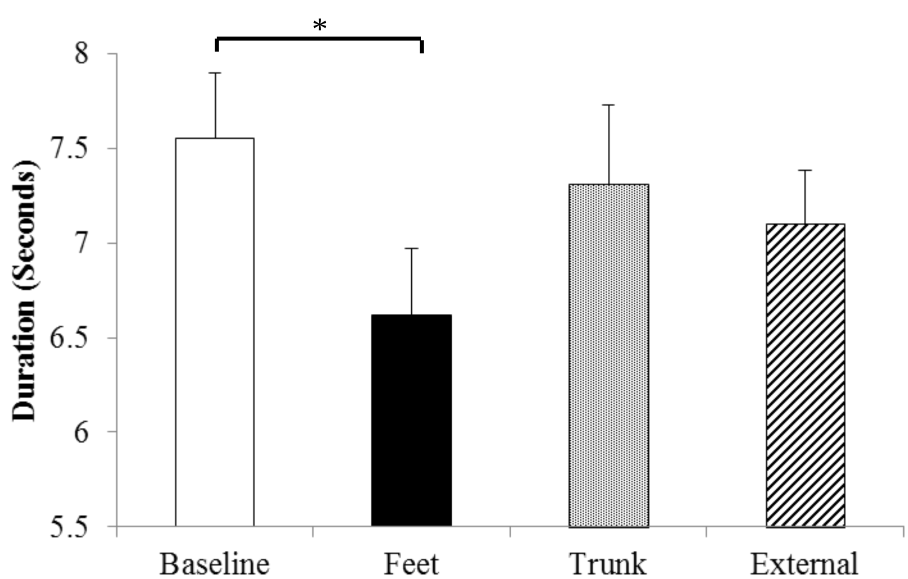

Figure 5. Effects of instruction condition on Duration (feet < baseline p = 0.013). Error bars represent standard error of the mean.

Table 8. Summary of Significant F-Statistics (Levels of Significance) for the instruction and trial main effects, and the instruction by trial interaction effect for trunk sway and duration measures for the normal walk task.

Measure	**Instruction Main Effect**	**Trial Main Effect**	**Instruction-by-Trial Interaction**
Roll Angle	$\boldsymbol{F_{(3,27)} = 5.837, p = 0.003}$	$F_{(2,18)} = 3.236, p = 0.063$	$F_{(4,34)} = 1.359, p = 0.269$
Roll Velocity	$F_{(3,27)} = 2.733, p = 0.063$	$F_{(2,18)} = 3.956, p = 0.038$	$F_{(4,40)} = 0.295, p = 0.897$
Yaw Angle	$F_{(3,27)} = 3.953, p = 0.019$	$F_{(2,18)} = 0.737, p = 0.492$	$F_{(6,54)} = 0.671, p = 0.673$
Yaw Velocity	$F_{(2,15)} = 3.412, p = 0.066$	$F_{(2,18)} = 0.762, p = 0.481$	$F_{(2,22)} = 0.595, p = 0.590$
Duration	$\boldsymbol{F_{(3,27)} = 5.985, p = 0.003}$	$F_{(2,18)} = 3.912, p = 0.039$	$F_{(6,54)} = 0.942, p = 0.473$

4.3.2 180° Turn Task

4.3.2.1 Approach to the Turn

4.3.2.1.1 Yaw Angle and Velocity

Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of instruction on yaw angle ($\chi^2(5) = 17.12$, $p < .05$) and yaw velocity ($\chi^2(5) = 19.68$, $p < .05$). Therefore, the degrees of freedom were corrected using the Huynh-Feldt estimates of sphericity ($\varepsilon = 0.63$ for main effect of yaw angle, and $\varepsilon = .59$ for main effect of yaw velocity). With this correction, an instruction main effect was observed for yaw angle ($F_{2,21}$=5.014; p=0.018) and yaw velocity ($F_{2,20}$=9.071; p=0.002). Yaw angle was significantly larger for the feet instruction condition compared to external instruction condition (p=0.049) (Figure 6A). Yaw velocity was greater during the feet instruction condition compared to both the no instruction (p=0.036) and external (p=0.003) instruction conditions (Figure 6B). No trial main effect or instruction-by-trial interaction effect was observed for yaw angle or velocity.

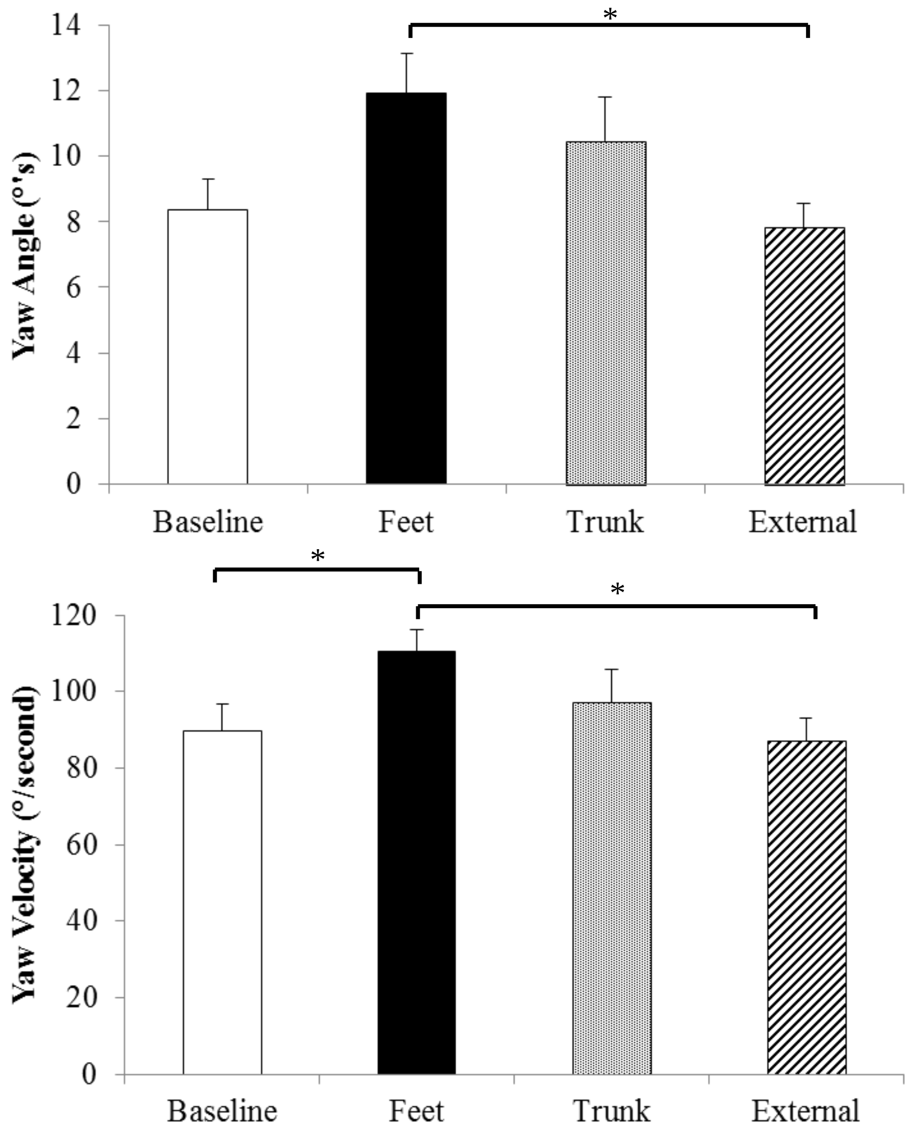

Figure 6. Effects of instruction condition on A) yaw angle (feet > external $p = 0.049$), and B) yaw velocity (feet > baseline $p = 0.036$ and external $p = 0.003$). Error bars represent standard error of the mean.

4.3.2.1.2 Roll Angle and Velocity

Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of instruction on roll angle ($\chi^2(5) = 17.82$, $p < .05$). Therefore, degrees of freedom were corrected using the Huynh-Feldt estimates of sphericity ($\varepsilon = .68$). With this correction, there was an instruction main effect observed for roll angle ($F_{2,23}$=15.381; p<0.001) and roll velocity ($F_{3,33}$=7.707; p<0.001). Roll angle was larger during the feet instruction condition compared to all other instruction conditions (no instruction, p=0.002; trunk, p=0.044; and external, p=0.002) (Figure 7A). Roll velocity was greater during the feet instruction condition compared to both the no instruction (p=0.042) and external (p=0.002) instruction conditions (Figure 7B). No trial main effect or instruction-by-trial interaction effect was observed for roll angle or roll velocity.

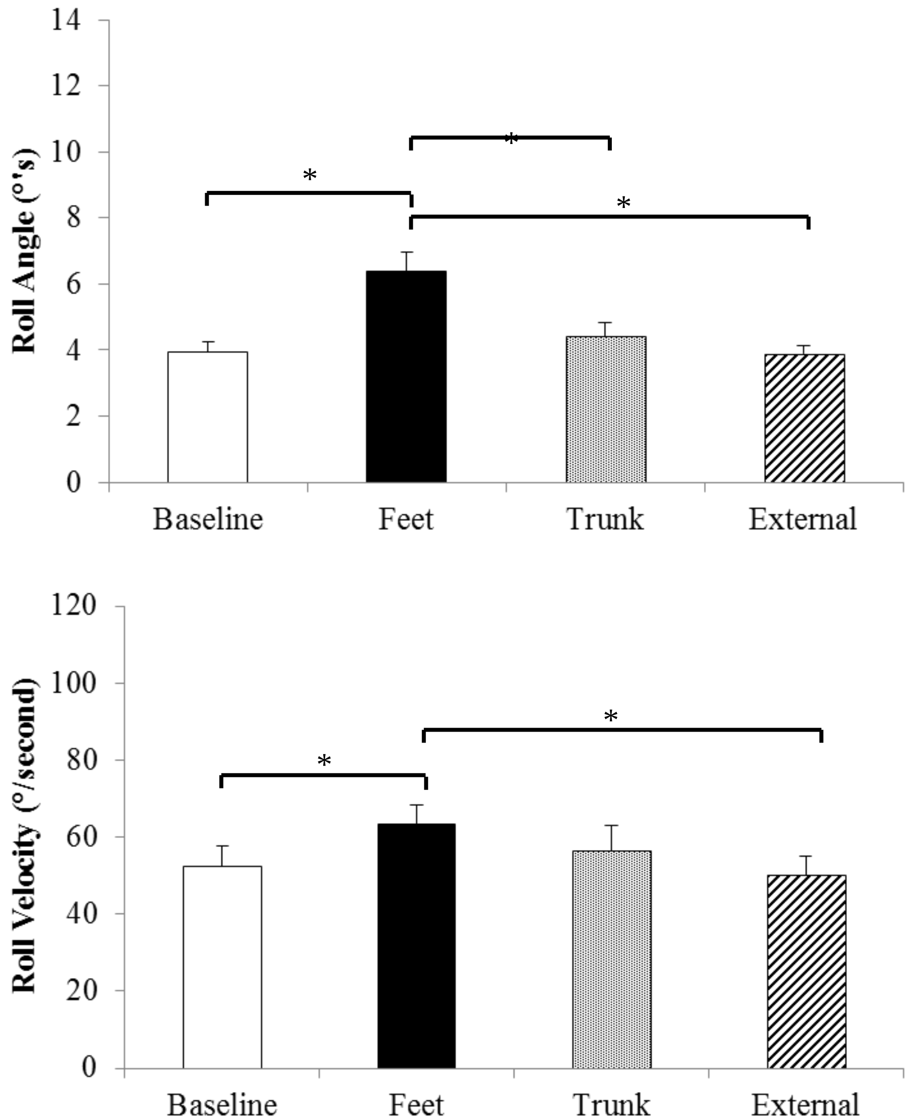

Figure 7. Effects of instruction condition on A) roll angle (feet > baseline p = 0.002, trunk p = 0.044, and external p = 0.002), and B) roll velocity (feet > baseline p = 0.042 and external p = 0.002). Error bars represent standard error of the mean.

Table 9. Summary of Significant F-Statistics (Levels of Significance) for the instruction and trial main effects, and the instruction by trial interaction effect for trunk sway and duration measures for the 180° turn task, approach to the turn phase.

Measure	Instruction Main Effect	Trial Main Effect	Instruction-by-Trial Interaction
Roll Angle	$\boldsymbol{F_{(2,23)} = 15.381, p < 0.001}$	$F_{(2.22)} = 1.725, p = 0.201$	$F_{(6,65)} = 1.162, p = 0.338$
Roll Velocity	$\boldsymbol{F_{(3,33)} = 7.707, p < 0.001}$	$F_{(2.22)} = 0.454, p = 0.641$	$F_{(4,42)} = 0.207, p = 0.927$
Yaw Angle	$\boldsymbol{F_{(2,21)} = 5.014, p = 0.018}$	$F_{(2.22)} = 1.421, p = 0.263$	$F_{(4,42)} = 1.331, p = 0.275$
Yaw Velocity	$\boldsymbol{F_{(2,20)} = 9.071, p = 0.002}$	$F_{(2.22)} = 0.802, p = 0.461$	$F_{(6,66)} = 0.627, p = 0.708$

4.3.2.2 Turn Phase

4.3.2.2.1 Yaw Angle and Velocity

Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of instruction on yaw angle ($\chi^2(5) = 17.93, p < .05$). Therefore, degrees of freedom were corrected using the Huynh-Feldt estimates of sphericity ($\varepsilon = .63$). With this correction, no significant instruction main effect for yaw angle was found. There was a significant instruction main effect for yaw velocity ($F_{3,33}=7.943; p<0.001$). Yaw velocity was greater during the feet instruction condition compared to both the no instruction ($p=0.018$) and external instruction ($p=0.018$) conditions (Figure 8B). No trial main effect or instruction-by-trial interaction effect was observed for yaw angle or velocity.

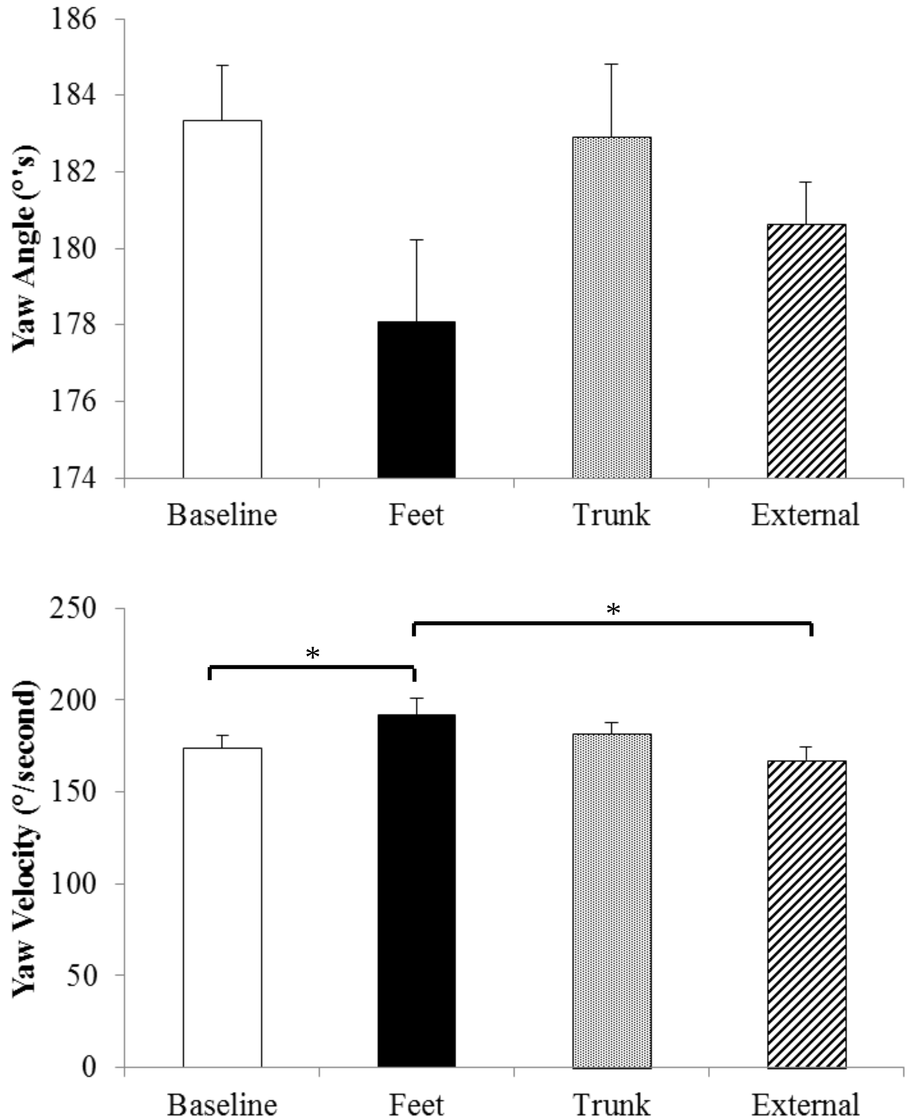

Figure 8. Effects of instruction condition on A) yaw angle (no differences), and B) yaw velocity (feet > baseline p = 0.018 and external p = 0.018). Error bars represent standard error of the mean.

4.3.2.2.2 Roll Angle and Velocity

Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of instruction on roll angle ($\chi^2(5) = 19.61$, $p < .05$) and roll velocity ($\chi^2(5) = 11.12$, $p < .05$). Therefore, the degrees of freedom were corrected using the Huynh-Feldt estimates of sphericity ($\varepsilon = 0.52$ for main effect of roll angle, and $\varepsilon = .71$ for main effect of roll velocity). With this correction, no significant instruction main effect for both roll angle and velocity was observed (Figure 9A and B). There was a significant trial main effect for roll velocity that was observed ($F_{2,22}=3.600$; $p=0.044$). The follow-up, Bonferroni corrected, comparisons did not reveal significant differences between trials for roll velocity. No trial main effect was observed for roll angle and no instruction-by-trial interaction effect was observed for roll angle or velocity.

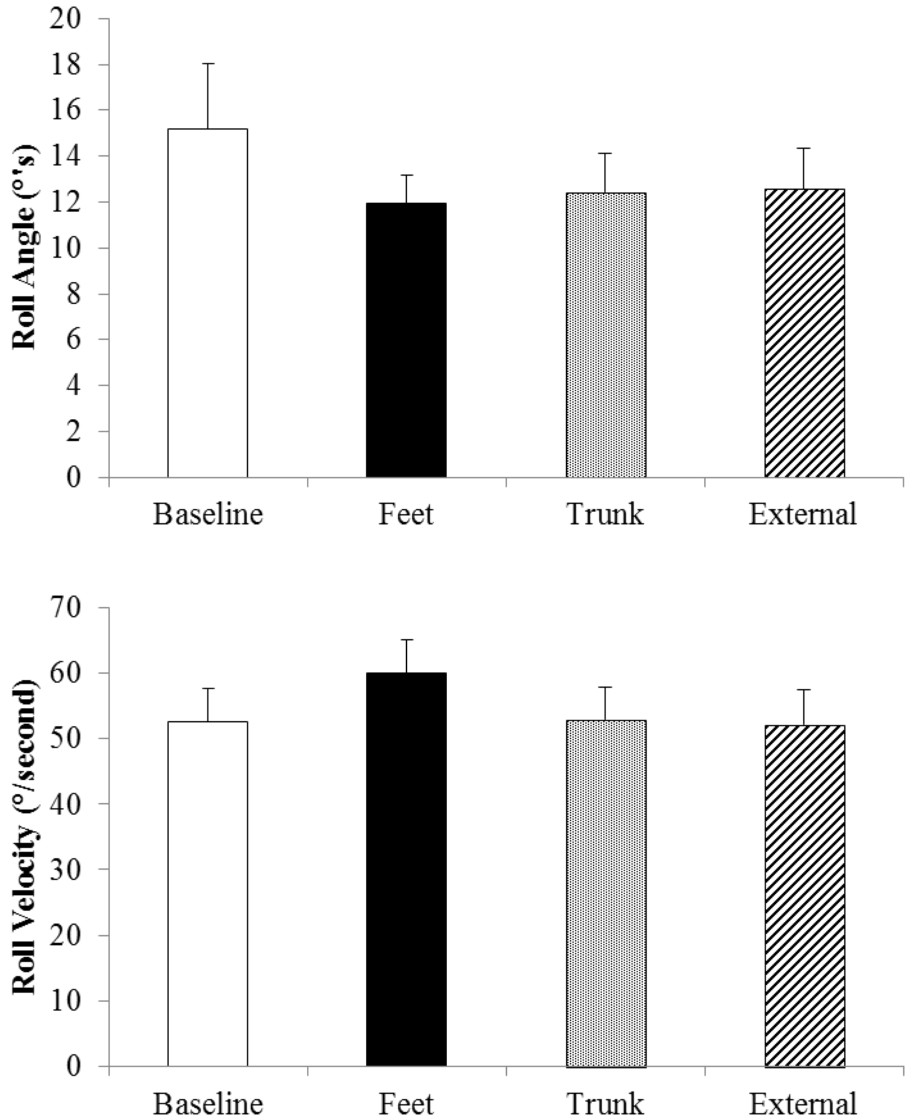

Figure 9. Effects of instruction condition on A) roll angle (no differences), and B) roll velocity (no differences). Error bars represent standard error of the mean.

4.3.2.2.3 Turn Duration

An instruction main effect was observed for turn duration ($F_{3,33}$=3.127; p=0.039). Follow-up comparisons, using Bonferroni correction, revealed no significant differences between instruction conditions. Although not significant, the feet instruction condition had the shortest turn duration times compared to all other conditions (Mean/SEM; baseline:2.68/.09, feet:2.48/.14, trunk:2.75/.11,external:2.71/.13; Figure 10). There was no significant trial main effect or instruction-by-trial interaction effect observed for task duration.

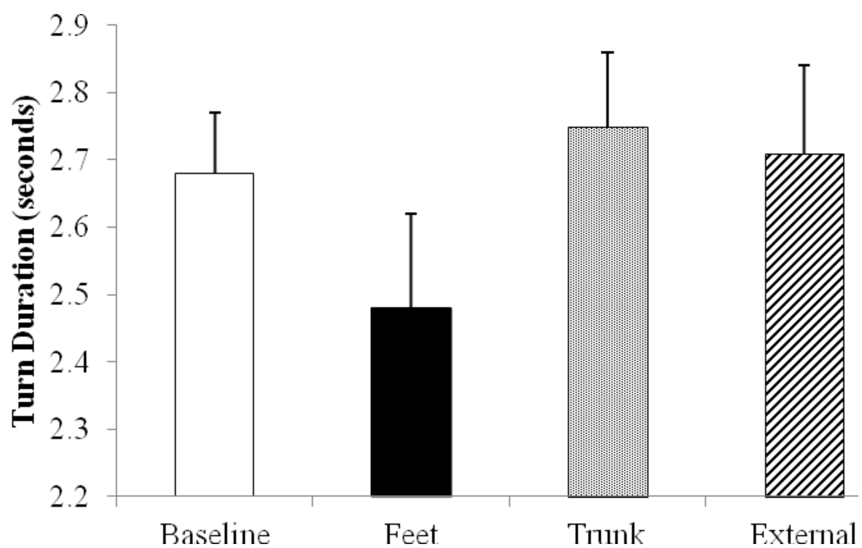

Figure 10. Effects of instruction condition on Duration (no difference). Error bars represent standard error of the mean.

Table 10. Summary of Significant F-Statistics (Levels of Significance) for the instruction and trial main effects, and the instruction by trial interaction effect for trunk sway and duration measures for the 180° turn task, turn phase.

Measure	Instruction Main Effect	Trial Main Effect	Instruction-by-Trial Interaction
Roll Angle	$F_{(2,17)} = 1.399$, $p = 0.268$	$F_{(2,22)} = 2.499$, $p = 0.105$	$F_{(6,66)} = 0.590$, $p = 0.737$
Roll Velocity	$F_{(2,23)} = 1.907$, $p = 0.169$	$F_{(2,22)} = 3.600$, $p = 0.044$	$F_{(6,66)} = 1.526$, $p = 0.183$
Yaw Angle	$F_{(2,21)} = 2.901$, $p = 0.080$	$F_{(2,22)} = 0.443$, $p = 0.648$	$F_{(6,66)} = 785$, $p = 0.585$
Yaw Velocity	$\boldsymbol{F_{(3,33)} = 7.943}$, $\boldsymbol{p < 0.001}$	$F_{(2,22)} = 1.868$, $p = 0.178$	$F_{(6,66)} = 0.281$, $p = 0.914$
Turn Duration	$F_{(3,33)} = 3.127$, $p = 0.039$	$F_{(2,22)} = 2.258$, $p = 0.128$	$F_{(6,66)} = 0.565$, $p = 0.756$

4.4 Self-reported Attention Focus Checks

Participants indicated multiple areas that they had attended to throughout the baseline (i.e., no instruction) condition (Table 11). For the normal walk task, 30% of participants (n = 3) stated that they had initially attended to an internal source (i.e., feet, arms, back, etc.). 30% of participants (n = 3) described focusing on an external source (i.e., tape marks, turn point, etc.) and nothing (n = 3). Furthermore, one participant had described using both internal and external sources to aid in the normal walk task. For the 180° turn task, 33.33% of participants (n = 4) stated that they had initially attended to an internal source, 16.67% an external source (n = 2), and 50% (n = 6) stated that they initially attended to nothing.

Participants were found to adhere to the simple verbal instructions administered prior to conducting each task and instruction condition. For the normal walk task, participants stated that on average, 97.4% (feet), 91.5% (trunk), and 96.0% (external) of the time they had focused entirely on the provided verbal instructions (Figure 11). For the 180° turn task, participants stated that on average, 95.3% (feet), 92.5% (trunk), and 96.5% (external) of the time they had focused entirely on the provided verbal instructions (Figure 12).

Table 11. Summary of no instruction condition responses to the question, "Was there anything within your own body and/or environment that you were thinking about when performing the task?"

Participants	**Normal Walk**	**180° Turn**
2	Red line & heel strike	Red line
3	Feet & knees	Feet & not falling
4	Nothing	Nothing
5	Red line	Turn point, where normally loose balance
6	How walking	Nothing
8	Nothing	Nothing
10	Red line	Feet
11	Feet	Feet
12	Red line	Nothing
15	Back (sore)	Nothing
16	Arm Swing	1^{st} step (Feet)
18	nothing	Nothing

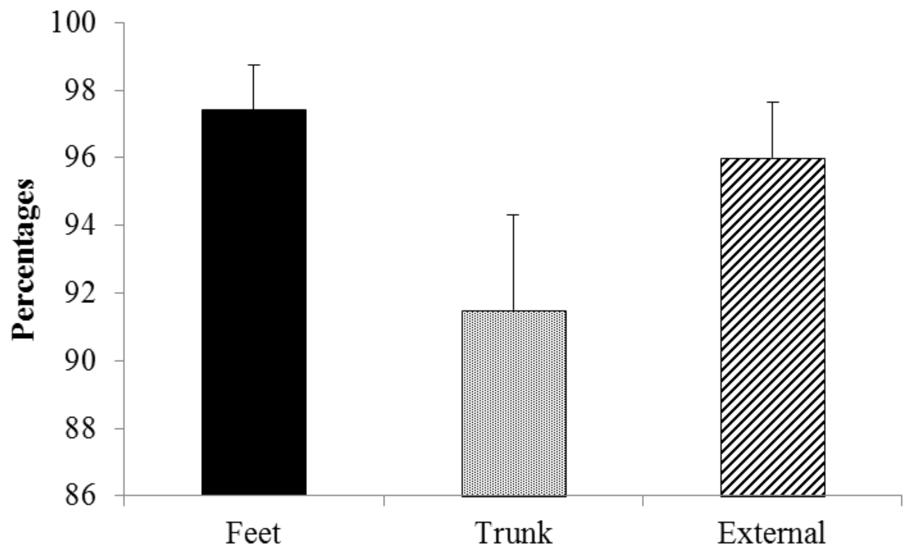

Figure 11. Normal walk task summary of participant responses to the question, "On a scale of 0 to 100%, with 0% representing not at all focused and 100% representing completely focused, how focused were you in adhering to the instructions provided to you for the task?" Error bars represent standard error of the mean

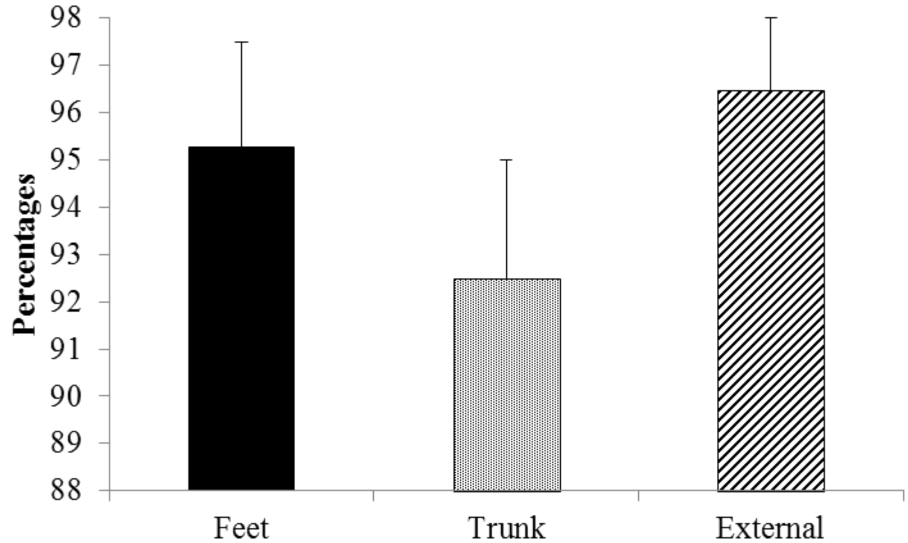

Figure 12. 180˚ task summary of participant responses to the question, "On a scale of 0 to 100%, with 0% representing not at all focused and 100% representing completely focused, how focused were you in adhering to the instructions provided to you for the task?" Black bars indicate feet instruction condition, textured bars indicate trunk instruction condition, and diagonal bars indicate external instruction condition. Error bars represent standard error of the mean.

CHAPTER 5: DISCUSSION

The purpose of this thesis was to examine the effect of verbal instruction on trunk sway and duration measures during normal walking and 180° turning tasks in individuals with PD. Four different instructional sets were compared, including no instruction, feet instruction (i.e., take big steps), trunk instruction (i.e., make larger movements of the trunk) and external instruction (i.e., focus on the end of the walkway or turning point) conditions. In general, the results of this thesis demonstrated that providing instruction related to step amplitude (i.e., take big steps) improved performance for both the normal walking and 180° turning tasks compared to providing no specific instruction or externally based instruction. Improvement was inferred through the observation of greater trunk sway and shorter durations on these tasks. Instruction related to the amplitude of trunk movement did not show improved performance on the normal walking and 180° turning tasks compared to providing no specific instruction or externally based instruction. There were also no differences in trunk sway and duration measures between the two internally amplitude based instruction conditions (i.e., take big steps and make larger movements of the trunk). The results of this thesis suggest that instructions related to step amplitude may facilitate walking and turning performance in PD.

5.1 Effect of Verbal Instruction on Normal Walking

The effect of verbal instruction on trunk sway and duration measures was examined for normal walking in order to replicate and extend previous findings that had shown benefits of verbal instruction for this type of task in PD. In terms of duration, instruction that directed an individual's attention to "take big steps" resulted in less time to complete a 6 meter normal walking task in PD compared to receiving no specific instruction. These findings are in support of previous research that showed an advantage of using amplitude based verbal instructions directed towards foot placement to increase walking velocity or to reduce the time needed to complete the task in PD (Baker et al, 2007; Behrman et al, 1998; Lehman et al, 2005; Farley & Koshland, 2005; Morris et al, 2009; Shaw et al, 2011; Werner & Gentile, 2003). Coupled with these changes in velocity and duration, alterations in gait parameters such as increased stride length have also been observed when using amplitude based instructional sets (Baker, et al., 2007; Behrman, et al., 1998; Farley & Koshland, 2005; Lehman, et al., 2005; Morris, et al., 2009; Shaw, et al., 2011; Werner & Gentile, 2003). However, as this thesis focused on quantifying trunk sway during the walking task, it can only be inferred that changes in gait parameters (i.e., increases in stride length) occurred when instructed to take big steps.

The instruction to take big steps also resulted in larger trunk roll angle sway compared to both the no instruction and externally based instruction conditions. There were no significant differences in trunk roll angle sway observed between the two internally based instruction conditions. These findings are in support of previous research that showed that amplitude based verbal instructions directed towards foot placement increased trunk roll and pitch angle and angular velocities during walking in PD (Shaw, et al., 2011). The increased trunk roll angle sway observed when instructed to take big steps in this thesis may be associated with the reduction in the time needed to complete the task (i.e., faster walking velocity resulted in increased trunk roll angle sway; Goutier, Jansen, Horlings, & Allum, 2010) or the increase may be associated with a change in trunk control strategy. An increase in trunk roll angle sway could be interpreted in two different ways. The increase in trunk roll angle sway may represent a reduction in axial rigidity in this direction. This increased trunk movement may be interpreted as improved walking performance as less rigid and/or constrained movement may allow additional flexibility to meet changing environmental and task demands that occur when walking and completing ADLs (Schenkman, et al., 2000). Alternatively, the increased trunk roll angle sway could be interpreted as poorer walking performance if reduced trunk movement was adopted as a compensatory strategy to maintain trunk stability (i.e., stiffening) when walking.

5.2 Effect of Verbal Instruction on 180° turning

The effect of verbal instruction on trunk sway and task duration measures was examined during turning in order to explore whether instruction can also benefit performance for more challenging tasks (i.e., beyond normal walking) in PD. The task was broken down into an approach phase and a turn phase based on previous research (Visser, et al., 2007) and the findings will be discussed separately.

5.2.1 Approach Phase

Explicit instructions directing an individual's attention to "take big steps" resulted in greater trunk sway when approaching the turn. Specifically, this instructional set resulted in greater trunk roll angle sway compared to all other types of instruction or no instruction at all, greater trunk yaw angle sway compared to externally based instructions, and greater trunk roll and yaw angular velocities compared to both no instructions at all or externally based instruction. These results observed during the approach to the turn are novel, as no research has examined the efficacy of verbal instructions on walking while approaching a 180° turn. However, these findings are similar in terms of the direction of change in trunk sway measures observed during the normal walking task previously discussed, with additional changes observed when approaching the turn and directing attention to “take big steps”. The task constraint of having to perform a turn may have resulted in the greater number of changes observed during the approach to the turn compared to normal walking with the instruction to take big steps. These additional changes may represent and/or convey some form of planning for the 180° turn. These findings show the importance of researching the approach to turning in individuals with PD as even though this act consists of straight path normal walking, differences in trunk control appear to emerge. The explanation of the potential benefit or drawback of greater trunk sway angle and angular velocities during the approach to the turn would be the same as for the normal walking task. For example, greater trunk sway may facilitate the upcoming turn or greater trunk sway may impair turning performance.

5.2.2 Turn Phase

Although deficits in turning are well described in PD (Crenna, et al., 2007; Gruendlinger, et al., 2005; Mak, et al., 2005; Mak, et al., 2008; Morris, et al., 2001; Schenkman, et al., 2000; Stack & Ashburn, 2008; Stack, et al., 2006; Vaugoyeau, et al., 2003; Visser, et al., 2007; Willems, et al., 2007) and research has shown that verbal instruction can benefit walking performance in PD (Baker, et al., 2007; Behrman, et al., 1998; Farley & Koshland, 2005; Lehman, et al., 2005; Morris, et al., 1996; Shaw, et al., 2011; Werner & Gentile, 2003), this thesis is the first to examine the effects of verbal instructions on turning performance in PD.

Explicit instructions directing an individual’s attention to “take big steps” resulted in improved turning performance as defined by increased trunk yaw angular velocity (i.e., turn rotation velocity). Specifically, trunk yaw angular velocity was found to significantly increase when focusing on taking big steps compared to both no instruction or externally based instructions. There were no significant differences observed between the two internally based instruction conditions for this measure. An increase in trunk yaw angular velocity during turning may be considered as an improvement in turning performance. Previous research has shown that individuals with PD have significantly reduced trunk yaw angular velocities when turning compared to healthy older adults (Visser, et al., 2007). Thus, an increase in trunk yaw angular velocity with the instruction to take big steps could be interpreted as normalizing trunk yaw angular velocity values to those more representative of a healthy older adult. This interpretation parallels that of increased stride length and faster walking velocities being normalized to the performance of healthy older adults when normal walking with amplitude based instructions (Baker et al, 2007; Behrman et al, 1998; Canning, 2005; Lehman et al, 2005; Farley & Koshland, 2005; Morris et al, 2009; Shaw et al, 2011; Werner & Gentile, 2003).

As a major component of a successful turn is trunk yaw angular velocity (Visser et al., 2007), an increase in the velocity of movement in this direction may help to counteract the typical bradykinetic turning strategy observed in PD and improve functional turning capabilities in this population (Visser, et al., 2007). The increased trunk yaw angular velocity may have also resulted from completing the turn in a shorter duration. However, turn duration was not found to be significant when comparing between instruction conditions (no instruction, 2.68 s; take big steps, 2.48 s; make large movements of the trunk, 2.75 s; focus on turn point, 2.71 s). Although the mean values are in the correct direction for this explanation (i.e., shorter turn durations when focusing on take big steps), the effect was non-significant.

The increase in trunk yaw angular velocity with the instruction to take big steps coupled with no changes in the roll direction can provide further support to suggest improved turning performance. Previous authors have concluded that during turning, a fall is more likely to occur in the medial-lateral, rather than the anterior-posterior direction (Cumming, et al., 1994). Therefore, in order to justify the efficacy for the use of verbal instructions during turning the ability to maintain lateral stability is important. The results of this thesis determined that when examining both trunk roll angle and angular velocity, no significant differences were observed between instruction conditions. In fact, trunk roll angle was lowest when focusing on take big steps (11.97 degrees) compared to the other instruction conditions (no instruction, 15.17 degrees; make large movements of the trunk, 12.43 degrees; focus on turn point, 12.57 degrees). This provides further evidence for the efficacy of using the instruction "take big steps" to improve functional turning as trunk yaw movement was facilitated while lateral stability was maintained with this instructional set (Cummings, et al., 1994; Visser, et al., 2007).

Directing attention to "take big steps" may have also changed the turning strategy implemented by this sample of PD participants. Individuals with PD are known to utilize a bradykinetic turn strategy when completing turns. These turn strategies have been commonly referred to as the 'wide-arc' and 'en-bloc' turning strategies. It appears logical to assume that incorporating these strategies would produce a reduction in trunk yaw angular velocity during turning. Therefore, the use of the instruction "take big steps" may have acted to change the turn strategy ultimately producing a turn that is more representative of a healthy older adult (i.e., increased yaw velocity; Visser, et al., 2007). Further exploration of changes in the spatial and temporal gait components associated with the turn task, coupled with trunk sway measures, could inform about this possible explanation.

Other researchers may argue that a reduction in trunk sway during turning may be interpreted as better performance. From the findings of Wulf and colleagues (2005, & 2009), it may be argued that a more stable turn would occur with reduced trunk sway especially when using an externally based instructional set. Accordingly, the findings of this body of research can explain the greater trunk sway observed with an internally based instructional set such as take big steps. This internal attention focus would act to constrain the coordination of the task and result in “worse” performance. However, this body of research has only focused on static balance tasks in PD in which reduced postural sway would equate to improved performance with the added constraint of standing as still as possible (Landers, et al., 2005; Wulf, et al., 2009).

For more dynamic tasks requiring walking and turning, specifically for individuals with PD, greater trunk sway may enhance performance by improving the ability of the system to adapt according to environmental and task constraints. Thus, it is important to consider the direction of sway and its association with “poor” or “better” performance when examining the effects of instruction on different tasks especially in individuals with PD. For example, the increased trunk sway during the approach to the turn and the turn phases with instructions to take big steps is opposite to the findings of Shaw and colleagues (2011) who found reductions in trunk sway when individuals with PD were asked to walk as fast as possible and use amplitude based instructions related to foot placement compared to walking as fast as possible and not using these instructions. However, the nature of the task constraint may explain these opposite findings. For example, instructions to take big steps may generate greater trunk sway to assist in preparing for and performing the turn. Thus, increased trunk sway would facilitate performance. When walking as fast as possible and given amplitude based instructions related to foot placement, trunk stability is prioritized and reductions in trunk sway were observed due to this constraint (Shaw, et al., 2011).

5.3 Explaining the Effect of Instruction on Walking and Turning Performance in PD

Recently, the literature has reported conflicting views regarding the area to where instructions should direct attention (i.e., internal and/or external) during performance. Wulf and colleagues have argued that directing an individual with PD to attend to their own movements (i.e., internal) degrades performance compared to directing attention to an outside source within the environment (i.e., external; Landers, et al., 2005; Wulf, et al., 2009). These authors have used the 'constrained action hypothesis' to explain the benefits associated with incorporating an external focus of attention. The hypothesis states that focusing on an internal source actively intervenes with automatic control processes whereas focusing on an external source promotes a more automatic, unconscious control of the required movement ultimately resulting in superior performance and/or learning (Wulf, et al., 2009). Importantly, these studies conducted on individuals with PD have only evaluated stationary balance tasks in which "better" performance was described as a reduction in postural sway (Landers, et al., 2005; Wulf, et al., 2009). However, in the current thesis, more dynamic walking and turning tasks were used. There is the potential for tasks of a dynamic nature to require greater flexibility of movement in order to adapt to the changing task and environmental constraints placed on the individual. Therefore, a reduction in postural sway may not always be considered as improved performance depending on the task.

In general, the current thesis found greater trunk sway and reductions in the time needed to complete the task when focusing on “take big steps”. Previous authors have described the benefits associated with incorporating attentional strategies in PD as improving performance by bypassing the defective BG, ultimately promoting improved functional performance on walking tasks (Canning, 2005; Morris, et al., 2010). Specifically, Morris and colleagues (2010) describe the use of movement strategy training as “using the frontal cortex to regulate movement size or timing by consciously thinking about the desired movement”. Studies investigating the effects of instructions on internally initiated movement have found increased activation of the supplementary motor area activity of the brain providing further proof for altered brain activity when utilizing simple verbal instructions directing attention towards specific aspects of the task (Cunnington, et al., 1999). Therefore, the use of the instruction “take big steps” may have activated different, intact regions of the brain, enabling improved performance during both normal walking and turning tasks.

When evaluating the verbal instruction “make larger movements of the trunk”, it is interesting to note that minimal effects were observed. That is, the trunk instruction was not significantly different from any other instruction condition. One possible explanation for this finding is that the trunk could potentially be yielding something of interest, however there is not enough to show a difference between the other instruction conditions. Another possible explanation could be that participants may have had difficulty internalizing the instructions provided (i.e., make larger movements of your trunk). That is, participants may have had difficulty acknowledging what their trunk actually was as well as how to manipulate it according to the instructions provided. This added difficulty may be representative of the fact that the trunk can move in the pitch, roll, and yaw directions. Furthermore, since axial rotations about the trunk are paramount to turning (Imai, et al., 2001; Patla, et al., 1991), directing attention to this key area may have resulted in some form of breakdown in coordination, ultimately reducing normal walking and turning functionality. This argument may parallel Wulf and colleagues breakdown in an internal focus of attention argument. That is, the "take bigger steps" instruction could be argued as a form of distal internal focus and the "make larger movements of your trunk" could be argued as the main internal focus for the turning phase. However, this still does not explain the reason for no significant difference being found between the two instruction conditions.

When evaluating the verbal instruction "focus on the end or turn point", it is interesting to note that trunk sway measures were reduced compared to the instruction to take big steps. In addition, no significant differences were found between the externally based instruction condition and the no instruction conditions. This reduction in postural sway does follow previous findings evaluating the effectiveness of verbal instructions in PD (Landers, et al., 2005; Wulf, et al., 2009). However, this may not be conducive for improved performance on the current tasks evaluated. In fact, one could make the argument that a subtle increase in trunk control is beneficial as the movement is being carried out in a less 'constrained' form. Morris (2009) even states that the notion of reduced postural sway during static balance tasks typically used by Wulf and colleagues needs to be refined as reductions in postural sway occur as a result of hypokinesia typically described in PD. Keeping this in mind, Wulf and colleagues may argue that the reason for no difference found between the external instruction and no instruction conditions is because the instructions may actually be similar in nature. That is, the only difference between the two instruction conditions is directing attention towards the “end point” and “turn point”. It could be argued that during all conditions, some focus was already garnered towards these two points, therefore providing verbal instructions to focus at these two points provided no further advantage.

The results of this thesis appear to advocate for the use of the instruction “take bigger steps” in order to improve both normal walking and 180° turning in individuals with PD. The use of this instruction appears to direct the individuals attention to one key component of gait, ‘take big steps’. The argument can be made that this instruction appears to ‘free-up’ the trunk rigidity, thus allowing for a more fluid form of movement when walking and turning.

5.4 Limitations

It is acknowledged that the current thesis was not without limitations. First, it cannot be determined whether or not the use of verbal instructions improves normal walking and turning performance for all individuals with PD. That is, these findings can only be generalized to the current sample investigated. For example, the effect of instructions on walking and turning performance may differ according to severity of disease, balance confidence, and/or other clinical measures. For example, with further losses of automaticity of movement with the progression of the disease, instructional sets may produce differential effects on performance.

With respect to the manipulation check asked after each instruction block, it is still difficult to ascertain the true adherence to the instructions provided by each individual. The participants may have simply provided a percentage, without providing a true estimate of how focused they had been throughout the trials. This may confound the current results, as the appropriate verbal instructions may have not been used according to the instruction condition. Furthermore, since only an adherence percentage estimate was used after each three trial block, it is undetermined whether or not adherence levels regarding instructions changed throughout each respective trial. That is, it cannot be determined if participants concentrated more so during the first trial of each block and then concentration reductions followed with each trial. This information may be valuable in a clinical and real-life setting.

While the trunk sway measures provide valuable information related to trunk control, spatial and temporal gait parameters were not collected in this thesis and thus it cannot be determined whether the use of verbal instructions changed the turning strategies of the participants.

Lastly, the content of the verbal instructions may have influenced the results of this thesis. For example, it is possible that a ‘true’ external instruction condition was not used in this thesis as it may be suggested that the no instruction condition and the externally based instruction condition were the same, which may explain the resulting lack of changes observed for this condition compared to the other instructional sets.

5.5 Future Directions

Future studies examining the effects of verbal instructions on individuals with PD during walking and turning tasks should couple both trunk sway and spatial and temporal gait and turning parameters to better understand the changes in turning strategy and postural stability occurring as a result of providing verbal instructions. Another potential future direction could be focusing on the effects that verbal instructions have on altered task difficulties. That is, to examine different types of turns and different magnitudes of turns to determine if the findings discussed in this thesis hold true with changing task constraints (i.e., turn magnitude). Another interesting area to evaluate would be to determine if verbal instructions have differing effects depending on the severity of the disease for individuals with PD. This would provide valuable information to movement specialists as it is important to know how instructions may influence each individual. Lastly, it would be important to determine the long term beneficial effects of providing verbal instructions to determine if PD individuals can retain and utilize these improvements during real-life ADLs.

5.6 Conclusions

Compared to no instructions or other internally or externally based instructional sets, the use of instructions directing individuals with PD to focus on "taking big steps" appeared to result in improved performance for walking and 180˚ turning. Therefore, individuals with mild to moderate PD were able to use simple amplitude based verbal instructions to improve walking and turning performance. Further research is required to determine the long term effects of verbal instructions on walking and turning performance in PD, and whether these effects can transfer to daily life situations.

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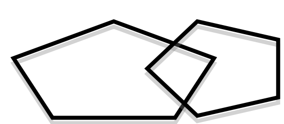
Appendix A – Mini-Mental State Examination (MMSE)

Instructions: Score one point for each correct response within each question of activity.

Maximum Score	Patient's Score	Questions
5		"What is the year? Season? Date? Day? Month?"
5		"Where are we now? Province? Town/city? Hospital? Floor?"
3		The examiner names three unrelated objects clearly and slowly, then the instructor asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until the patient learns all of them, if possible.
5		"I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, …) Alternative: "Spell WORLD backwards." (D-L-O-R-W)
3		"Earlier I told you the names of three things. Can you tell me what those were?"
2		Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them."
1		"Repeat the phrase: 'No ifs, ands, or buts."
3		"Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.)
1		"Please read this and do what it says." (Written instruction is "Close your eyes.")
1		"Make up and write a sentence about anything." (This sentence must contain a noun and a verb.)
1		"Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.) 
30		TOTAL

Appendix B – Modified Hoehn & Yahr Scale (H&Y)

Stage 0	No signs of disease
Stage 1	Unilateral disease
Stage 1.5	Unilateral plus axial involvement
Stage 2	Bilateral disease, without impairment of balance
Stage 2.5	Mild bilateral disease, with recovery on pull test
Stage 3	Mild to moderate bilateral disease; some postural instability; physically independent
Stage 4	Severe disability; still able to walk or stand unassisted
Stage 5	Wheelchair bound or bedridden unless aided

Appendix C – Unified Parkinson's Disease Rating Scale – Motor Subscale III (UPDRS)

3.1 SPEECH

0: Normal:	No speech problems.
1: Slight:	Loss of modulation, diction or volume, but still all words easy to understand.
2: Mild:	Loss of modulation, diction, or volume, with a few words unclear, but the overall sentences easy to follow.
3: Moderate:	Speech is difficult to understand to the point that some, but not most, sentences are poorly understood.
4: Severe:	Most speech is difficult to understand or unintelligible.

3.2 FACIAL EXPRESSION

0: Normal:	Normal facial expression.
1: Slight:	Minimal masked facies manifested only by decreased frequency of blinking.
2: Mild:	In addition to decreased eye-blink frequency, Masked facies present in the lower face as well, namely fewer movements around the mouth, such as less spontaneous smiling, but lips not parted.
3: Moderate:	Masked facies with lips parted some of the time when the mouth is at rest.
4: Severe:	Masked facies with lips parted most of the time when the mouth is at rest.

3.3 RIGIDITY

0: Normal:	No rigidity.
1: Slight:	Rigidity only detected with activation maneuver.
2: Mild:	Rigidity detected without the activation maneuver, but full range of motion is easily achieved.
3: Moderate:	Rigidity detected without the activation maneuver; full range of motion is achieved with effort.
4: Severe:	Rigidity detected without the activation maneuver and full range of motion not achieved.

3.4 FINGER TAPPING

0: Normal:	No problems.
1: Slight:	Any of the following: a) the regular rhythm is broken with one or two interruptions or hesitations of the tapping movement; b) slight slowing; c) the amplitude decrements near the end of the 10 taps.
2: Mild:	Any of the following: a) 3 to 5 interruptions during tapping; b) mild slowing; c) the amplitude decrements midway in the 10-tap sequence.
3: Moderate:	Any of the following: a)more than 5 interruptions during tapping or at least one longer arrest (freeze) in ongoing movement; b) moderate slowing; c) the amplitude decrements starting after the 1^{st} tap.

4: Severe: Cannot or can only barely perform the task because of slowing, interruptions or decrements.

3.5 HAND MOVEMENTS

0: Normal: No problem.

1: Slight: Any of the following: a) the regular rhythm is broken with one or two interruptions or the hesitations of the movement; b) slight slowing; c) the amplitude decrements near the end of the task.

2: Mild: Any of the following: a) 3 to 5 interruptions during the movements; b) mild slowing; c) the amplitude decrements midway in the task.

3: Moderate: Any of the following: a) more than 5 interruptions during the movement or at least one longer arrest (freeze) in ongoing movement; b) moderate slowing; c) the amplitude decrements starting after the 1^{st} open-and-close sequence.

4: Severe: Cannot or can only barely perform the task because of slowing, interruptions or decrements.

3.6 PRONATION-SUPINATION MOVEMENTS OF HANDS

0: Normal: No problems.

1: Slight: Any of the following: a) the regular rhythm is broken with one or two interruptions or hesitations of the movements; b) slight slowing; c) the amplitude decrements near the end of the task.

2: Mild: Any of the following: a) 3 to 5 interruptions during the movements; b) mild slowing; c) the amplitude decrements midway in the task.

3: Moderate: Any of the following: a) more than 5 interruptions during the movement or at least one longer arrest (freeze) in ongoing movement; b) moderate slowing; c) the amplitude decrements starting after the 1^{st} open-and-close sequence.

4: Severe: Cannot or can only barely perform the task because of slowing, interruptions or decrements.

3.7 TOE TAPPING

0: Normal: No problem.

1: Slight: Any of the following: a) the regular rhythm is broken with one or two interruptions or hesitations of the movements; b) slight slowing; c) the amplitude decrements near the end of the task.

2: Mild: Any of the following: a) 3 to 5 interruptions during the movements; b) mild slowing; c) the amplitude decrements midway in the task.

3: Moderate: Any of the following: a) more than 5 interruptions during the movement or at least one longer arrest (freeze) in ongoing movement; b) moderate slowing; c) the amplitude decrements starting after the 1^{st} open-and-close sequence.

4: Severe: Cannot or can only barely perform the task because of slowing, interruptions or decrements.

3.8 LEG AGILITY

0: Normal:	No problems.
1: Slight:	Any of the following: a) the regular rhythm is broken with one or two interruptions or hesitations of the movements; b) slight slowing; c) the amplitude decrements near the end of the task.
2: Mild:	Any of the following: a) 3 to 5 interruptions during the movements; b) mild slowing; c) the amplitude decrements midway in the task.
3: Moderate:	Any of the following: a) more than 5 interruptions during the movement or at least one longer arrest (freeze) in ongoing movement; b) moderate slowing; c) the amplitude decrements starting after the 1st open-and-close sequence.
4: Severe:	Cannot or can only barely perform the task because of slowing, interruptions or decrements.

3.9 ARISING FROM CHAIR

0: Normal:	No problems. Able to arise quickly without hesitation.
1: Slight:	Arising is slower than normal; or may need more than one attempt; or may need to move forward in the chair to arise. No need to use the arms of the chair.
2: Mild:	Pushes self-up from arms of chair without difficulty.
3: Moderate:	Needs to push off, but tends to fall back; or may have to try more than one time using arms of chair, but can get up without help.
4: Severe:	Unable to arise without help.

3.10 GAIT

0: Normal:	No problems.
1: Slight:	Independent walking with minor gait impairment.
2: Mild:	Independent walking but with substantial gait impairment.
3: Moderate:	Requires an assistance device for safe walking (walking stick, walker) but not a person.
4: Severe:	Cannot walk at all or only with another person’s assistance.

3.11 FREEZING OF GAIT

0: Normal:	No freezing.
1: Slight:	Freezes on starting, turning or walking through doorway with a single halt during any of these events, but then continues smoothly without freezing during straight walking.
2: Mild:	Freezes on starting, turning or walking through doorway with more than one halt during any of these activities, but continues smoothly without freezing during straight walking.
3: Moderate:	Freezes once during straight walking.
4: Severe:	Freezes multiple times during straight walking.

3.12 POSTURAL STABILITY

0: Normal:	No problems: Recovers with one or two steps.
1: Slight:	3-5 steps, but subject recovers unaided.
2: Mild:	More than 5 steps, but subject recovers unaided.
3: Moderate:	Stands safely, but with absence of postural response; falls if not

caught by examiner.
4: Severe: Very unstable, tends to lose balance spontaneously or with just a gentle push on the shoulders.

3.13 POSTURE

0: Normal: No problems.
1: Slight: Not quite erect, but posture could be normal for older person.
2: Mild: Definite flexion, scoliosis or leaning to one side, but patient can correct posture to normal posture when asked to do so.
3: Moderate: Stooped posture, scoliosis or leaning to one side that cannot be corrected volitionally to a normal posture by the patient.
4: Severe: Flexion, scoliosis or leaning with extreme abnormality of posture.

3.14 GLOBAL SPONTANEITY OF MOVEMENT (BODY BRADYKINESIA)

0: Normal: No problems.
1: Slight: Slight global slowness and poverty of spontaneous movements.
2: Mild: Mild global slowness and poverty of spontaneous movements.
3: Moderate: Moderate global slowness and poverty of spontaneous movements.
4: Severe: Severe global slowness and poverty of spontaneous movements.

3.15 POSTURAL TREMOR OF THE HANDS

0: Normal: No tremor.
1: Slight: Tremor is present but less than 1 cm in amplitude.
2: Mild: Tremor is at least 1 cm but less than 3 cm in amplitude.
3: Moderate: Tremor is at least 3 cm but less than 10 cm in amplitude.
4: Severe: Tremor is at least 10 cm in amplitude.

3.16 KINETIC TREMOR OF THE HANDS

0: Normal: No tremor.
1: Slight: Tremor is present but less than 1 cm in amplitude.
2: Mild: Tremor is at least 1 cm but less than 3 cm in amplitude.
3: Moderate: Tremor is at least 3 cm but less than 10 cm in amplitude.
4: Severe: Tremor is at least 10 cm in amplitude.

3.17 REST TREMOR AMPLITUDE

Extremity Ratings

0: Normal: No tremor.
1: Slight: < 1 cm in maximal amplitude.
2: Mild: > 1 cm but < 3 cm in maximal amplitude.
3: Moderate: 3 – 10 cm in maximal amplitude.
4: Severe: > 10 cm in maximal amplitude.

Lip/Jaw Ratings

0: Normal: No tremor.
1: Slight: < 1 cm in maximal amplitude.
2: Mild: > 1 cm but < 2 cm in maximal amplitude.
3: Moderate: > 2 cm but < 3 cm in maximal amplitude.
4: Severe: > 3 cm in maximal amplitude.

3.18 CONSTANCY OF REST TREMOR

0: Normal:	No tremor.
1: Slight:	Tremor at rest is present < 25% of the entire examination period.
2: Mild:	Tremor at rest is present 26-50% of the entire examination period.
3: Moderate:	Tremor at rest is present 51-75% of the entire examination period.
4: Severe:	Tremor at rest is present > 75% of the entire examination period.

DYSKINESIA IMPACT OF PART III RATINGS

A. Were dyskinesia (chores or dystonia) present during examination? Y/N
B. If yes, did these movements interfere with your ratings? Y/N

Appendix D – Balance Confidence Questionnaire (ABC-F)

0____10____20____30____40____50____60____70____80____90____100

I do not feel at all confident	**I feel moderately confident**	**I feel completely confident**

Please use the scale to rate the <u>amount of confidence</u> you have in <u>avoiding a fall</u> when you have to:

Walk around house	________
Walk up/down stairs	________
Pick up object from floor	________
Reach forward	________
Reach forward on tiptoes	________
Stand on chair to reach object	________
Sweep the floor	________
Walk outside to nearby car	________
Get in/out of car	________
Walk across parking lot	________
Walk up/down ramp	________
Walk in crowded mall	________
Walk in crowd and bumped in to	________
Ride escalator holding rail	________
Ride escalator not holding rail	________
Walk on icy sidewalk	________

Appendix E – Ambulatory Self-Confidence Questionnaire (ASCQ)

0______1______2______3______4______5______6______7______8______9______10

Not at all confident	**Moderately confident**	**Extremely confident**

Please use the scale to rate the <u>amount of confidence</u> you have in your ability to walk in different environments independently, without losing your balance:

1. Step up onto a curb? ________
2. Step down off a curb ? ________
3. Walk up a ramp (mild incline)? ________
4. Walk down a ramp (mild incline)? ________
5. Walk up a flight of stairs (4 steps or more) with a handrail? ________
6. Walk down a flight of stairs (4 steps or more) with a handrail? ________
7. Cross a street with a timed crosswalk (walk signal)? ________
8. Cross a street without a timed crosswalk (walk signal)? ________
9. Walk on an uneven sidewalk? ________
10. Walk on grass? ________
11. Walk on slippery ground: for example icy or wet surfaces? ________
12. Walk in the dark or at night when it is difficult to see your feet?________
13. Walk through a crowded place: for example a busy street? ________
14. Walk and talk to a companion at the same time? ________
15. Carry small items while walking: for example a carton of milk?________
16. Stop walking suddenly to avoid an oncoming vehicle? ________
17. Use an escalator? ________
18. Use a moving sidewalk (one at a airport)? ________
19. Walk on a moving bus? ________
20. Walk from one room to another in your home? ________
21. Walk a short distance without stopping: for example from your home to a car? ________
22. Walk a long distance without stopping: for example from your home to a bus stop? ________

Appendix F – Movement Specific Reinvestment Scale – Trait (MSRS-T)

Below are a number of statements about your movements. The possible answers go from 'strongly agree' to 'strongly disagree'. There are no right or wrong answers so circle the answer that best describes how you feel for each question.

1. I rarely forget the times when my movements have failed me, however slight the failure.
   strongly disagree | moderately disagree | weakly disagree | weakly agree | moderately agree | strongly agree

2. I'm always trying to figure out why my actions failed.
   strongly disagree | moderately disagree | weakly disagree | weakly agree | moderately agree | strongly agree

3. I reflect about my movement a lot.
   strongly disagree | moderately disagree | weakly disagree | weakly agree | moderately agree | strongly agree

4. I am always trying to think about my movements when I carry them out.
   strongly disagree | moderately disagree | weakly disagree | weakly agree | moderately agree | strongly agree

5. I'm self-conscious about the way I look when I am moving.
   strongly disagree | moderately disagree | weakly disagree | weakly agree | moderately agree | strongly agree

6. I sometimes have the feeling that I'm watching myself alone.
   strongly disagree | moderately disagree | weakly disagree | weakly agree | moderately agree | strongly agree

7. I'm aware of the way my mind and body works when I am carrying out a movement.
   strongly disagree | moderately disagree | weakly disagree | weakly agree | moderately agree | strongly agree

8. I'm concerned about my style of moving.
   strongly disagree | moderately disagree | weakly disagree | weakly agree | moderately agree | strongly agree

9. If I see my reflection in a shop window, I will examine my movements.
   strongly disagree | moderately disagree | weakly disagree | weakly agree | moderately agree | strongly agree

10. I am concerned about what people think about me when I am moving.
    strongly disagree | moderately disagree | weakly disagree | weakly agree | moderately agree | strongly agree

Appendix G – New Freezing of Gait Questionnaire (NFOG-Q)

Part I – Distinction Freezer – non-Freezer, over the past month

1. Did you experience “freezing episodes” over the past month?

    i. I have not experienced such a feeling or episode over the past month
    ii. I have experienced such a feeling or episode over the past month.

If the answer is ‘I’ (patient is a freezer) complete part II and III. The sum of part II and III is the final NFOG score.

Part II – Freezing severity

2. How frequently do you experience freezing episodes?

    i. Less than once a week
    ii. Not often, about once a week
    iii. Often, about once a day
    iv. Very often, more than once a day

3. How frequently do you experience freezing episodes during turning?

    i. Never
    ii. Rarely, about one a month
    iii. Not often, about once a week
    iv. Often, about once a day
    v. Very often, more than once a day

If the answer is ‘ii’ or more go to question #4. If the answer is ‘i’, go directly to #5.

4. How long is your longest freezing episode during turning?

    i. Very short, 1 sec
    ii. Short, 2-5 s
    iii. Long, between 5 and 30 s
    iv. Very long, unable to walk for more than 30 s

5. How frequently do you experience episodes of freezing when initiating the first step?
    i. Never
    ii. Rarely, about once a month
    iii. Not often, about once a week
    iv. Often, about once a day
    v. Very often, more than once a day

If the answer ‘ii’ or more go to question #6. If the answer is ‘i’, go directly to #7.

6. How long is your longest freezing episode when initiating the first step?

    i. Very short, 1 s
    ii. Short, 2-5s
    iii. Long, between 5 and 30 s
    iv. Very long, unable to walk for more than 30 s

Part III – Freezing impact on daily life

7. How disturbing are the freezing episodes for your daily walking?

    i. Not at all
    ii. Very little
    iii. Moderately
    iv. Significantly

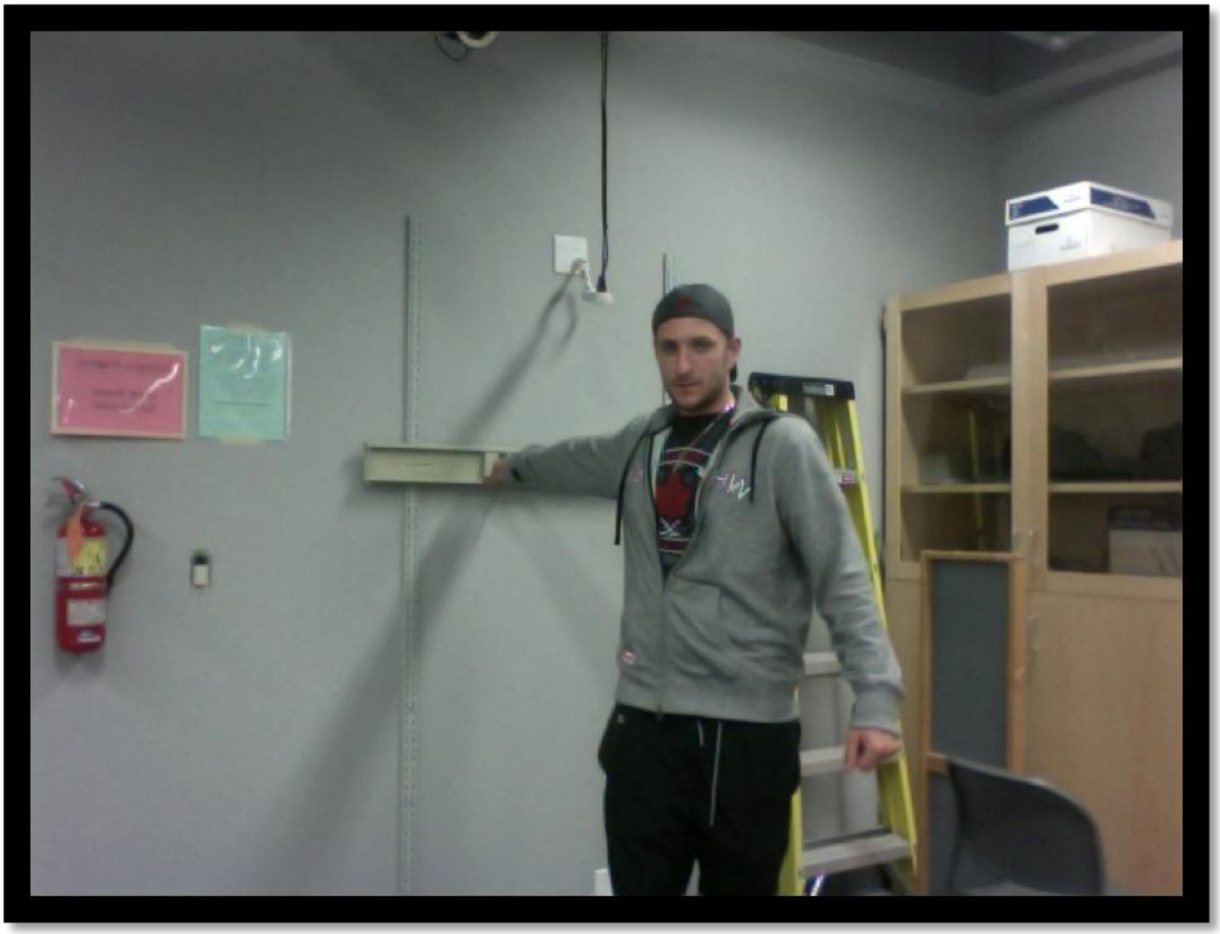
8. Do the freezing episodes cause feelings of insecurity and fear of falling?

    i. Not at all
    ii. Very little
    iii. Moderately
    iv. Significantly

9. Are your freezing episodes affecting your daily activities?
(Rate the impact of freezing on daily activities only. Not the impact of the disease in general).

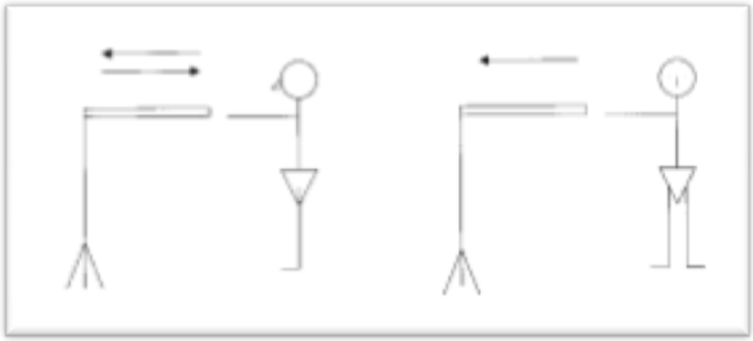
    i. Not at all, I continue doing things as normal
    ii. Mildly, I avoid only few daily activities
    iii. Moderately, I avoid a significant amount (about half) of daily activities
    iv. Severely, I am very restricted in carrying out most daily activities

Appendix H – Flexometer Task



Individual completing 'Flexometer'. Used as a measure of trunk flexibility.

Appendix I – Functional Reach Test



Individual completing Functional Reach test. Individual is required to reach forward as far as possible while keeping heels in contact with the floor.

Appendix J – Ethics Approval

Brock University
Research Ethics Office
Tel: 905-688-5550 ext. 3035
Email: reb@brocku.ca

Bioscience Research Ethics Board

Certificate of Ethics Clearance for Human Participant Research

DATE:	November 26, 2012		
PRINCIPAL INVESTIGATOR:	ADKIN, Allan - Kinesiology		
FILE:	11-152 - ADKIN		
TYPE:	Masters Thesis/Project	STUDENT:	JacobPfeiffer
		SUPERVISOR:	Allan Adkin

TITLE: Balance Control in individuals with Parkinson's Disease

ETHICS CLEARANCE GRANTED

Type of Clearance: MODIFICATION Expiry Date: 2/28/2013

The Brock University Bioscience Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement. Clearance granted from **11/26/2012** to **2/28/2013**.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before **2/28/2013**. Continued clearance is contingent on timely submission of reports.

To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Research Ethics web page at http://www.brocku.ca/research/policies-and-forms/research-forms.

In addition, throughout your research, you must report promptly to the REB:

a) Changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) All adverse and/or unanticipated experiences or events that may have real or potential unfavourable implications for participants;
c) New information that may adversely affect the safety of the participants or the conduct of the study;
d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Approved:

Brian Roy, Chair
Bioscience Research Ethics Board

Note: Brock University is accountable for the research carried out in its own jurisdiction or under its auspices and may refuse certain research even though the REB has found it ethically acceptable.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of research at that site.